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(51) INT CL<sup>6</sup>

H05K 7/20, H01L 23/46

(52) UK CL (Edition N)

H1R RBK

H1K KPDB K4C5M K5D1 K5D2 K5D5

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(58) Field of Search

UK CL (Edition M) H1K KPDB KPD X, H1R RBK  
INT CL<sup>6</sup> H01L 23/00 23/34 23/36 23/367 23/46 23/467  
23/473, H05K 7/00 7/20  
Online databases:WPI

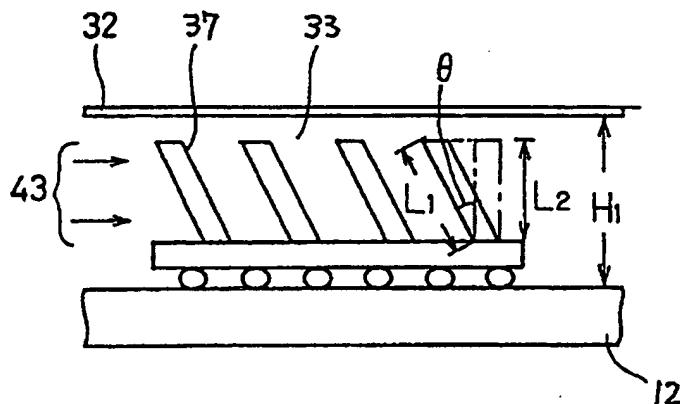
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(54) Semiconductor element cooling apparatus

(57) A semiconductor element cooling apparatus cools at least one semiconductor element mounted on a circuit substrate 12. A coolant flow 43 is obliquely hit by radiator fins 37. Alternatively an angled fan may provide a flow of angled coolant or partitions may provide reduced area gaps of increased coolant velocity.

FIG. 5



GB 2 280 989 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1

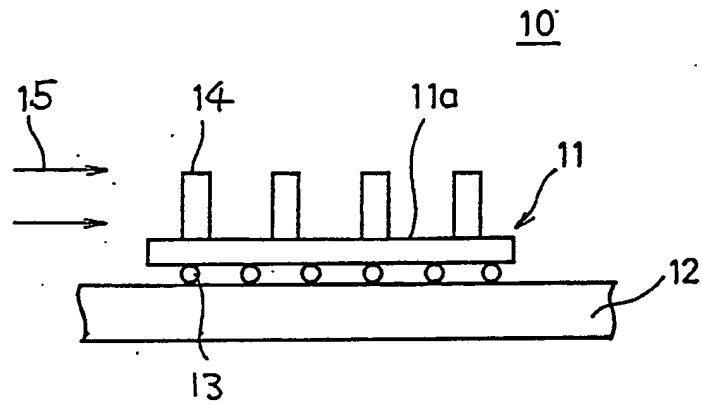


FIG. 2

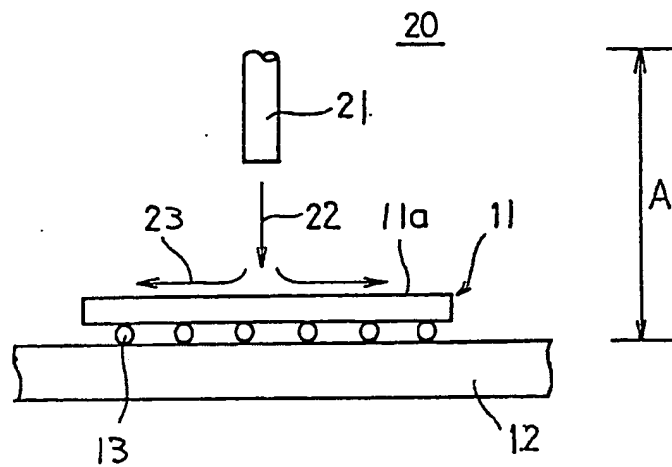


FIG. 3

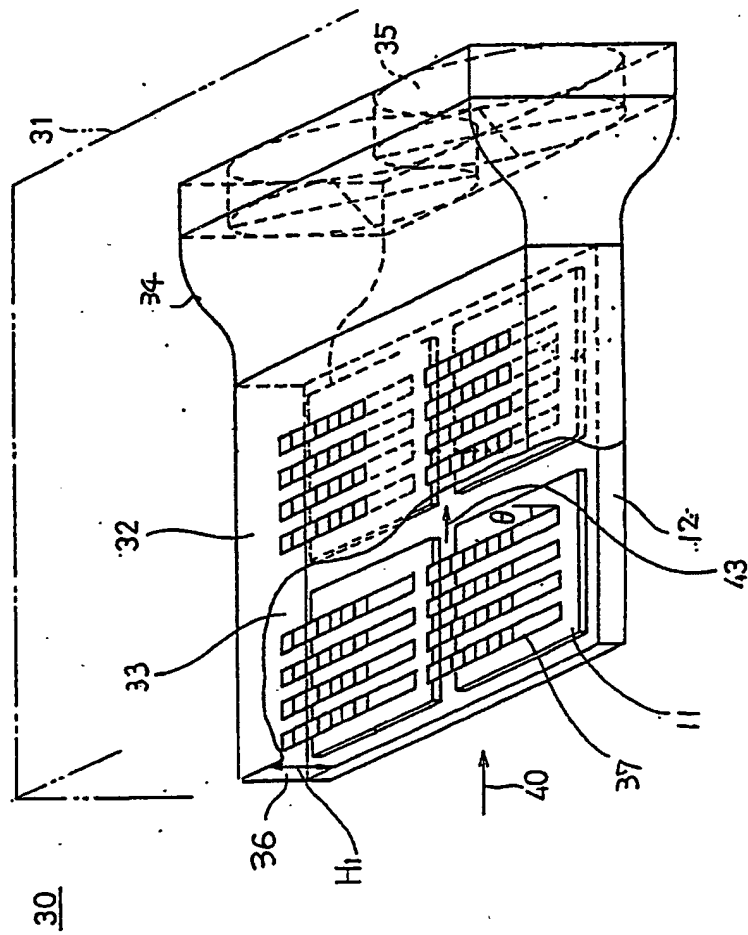


FIG. 4

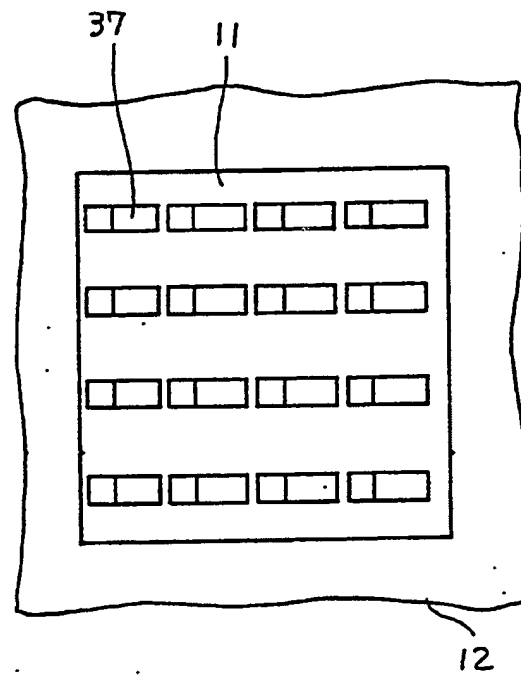


FIG. 5

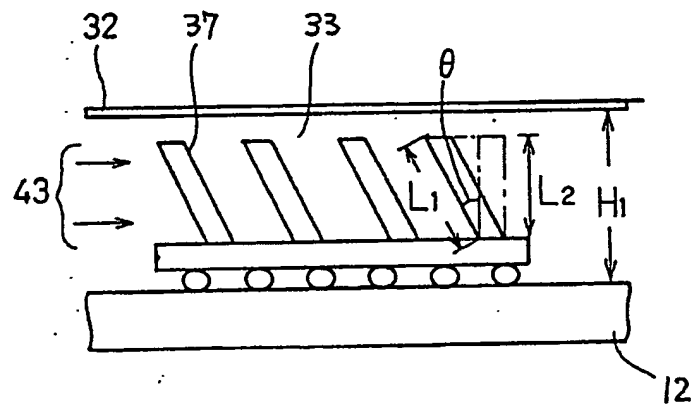


FIG. 6

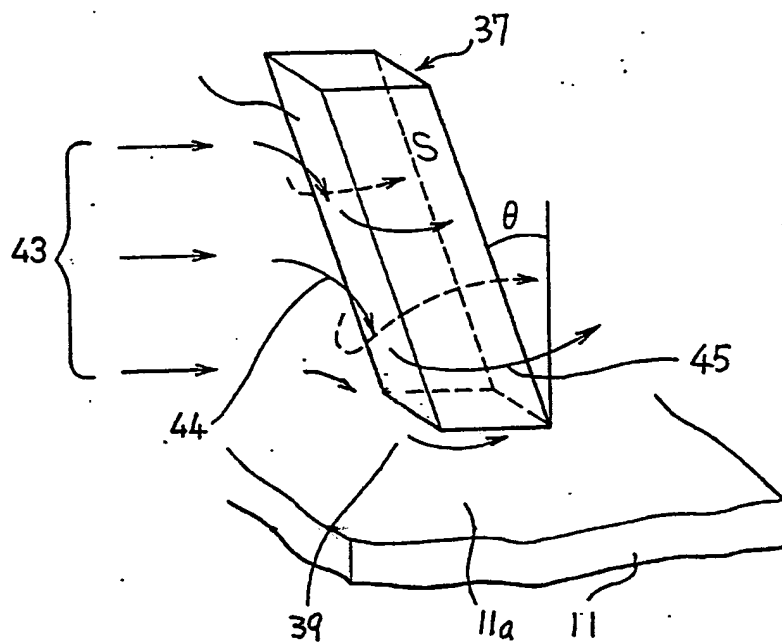


FIG. 7

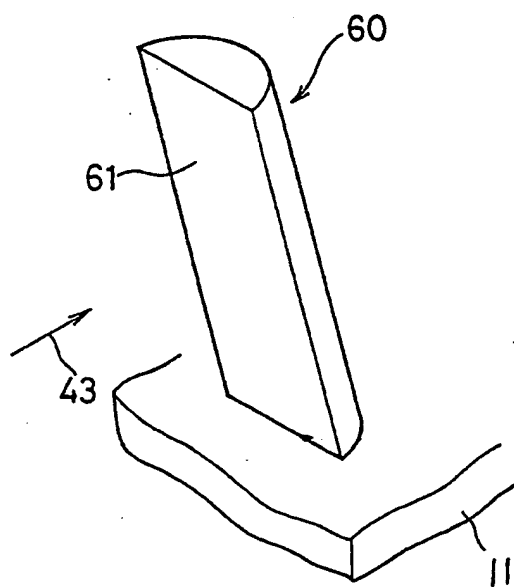


FIG. 8

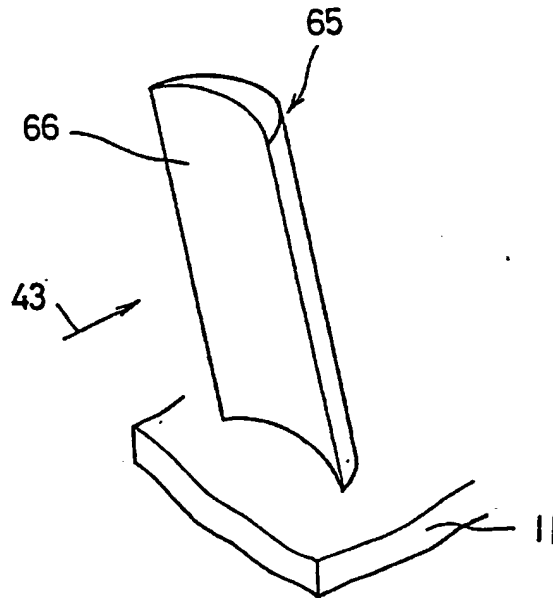


FIG. 9

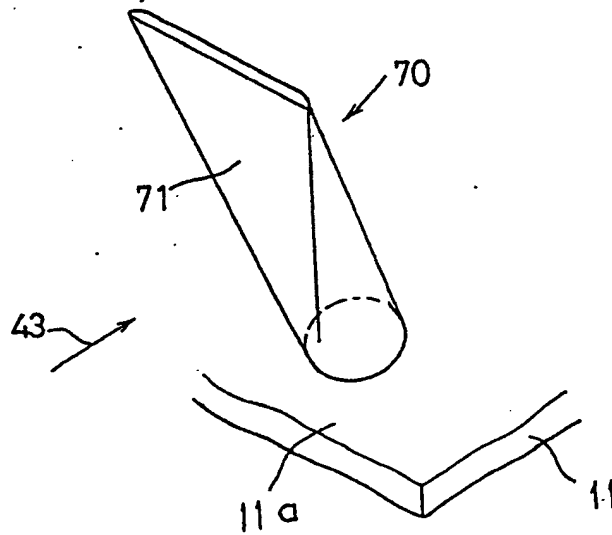


FIG. 10

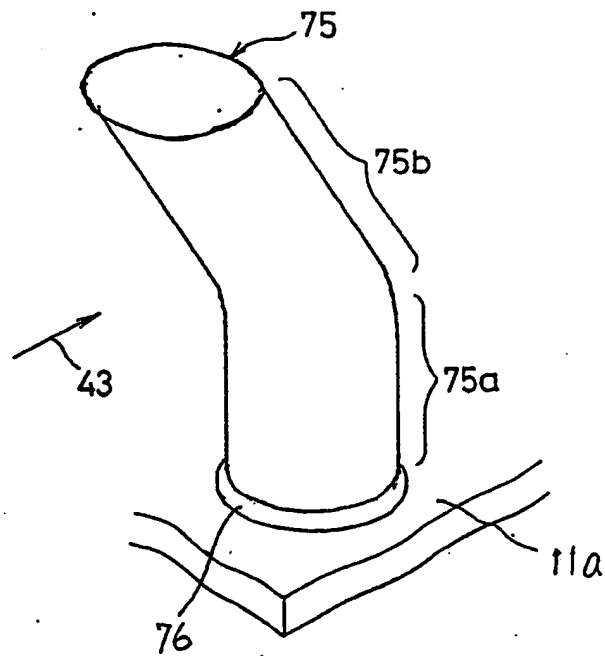


FIG. 11

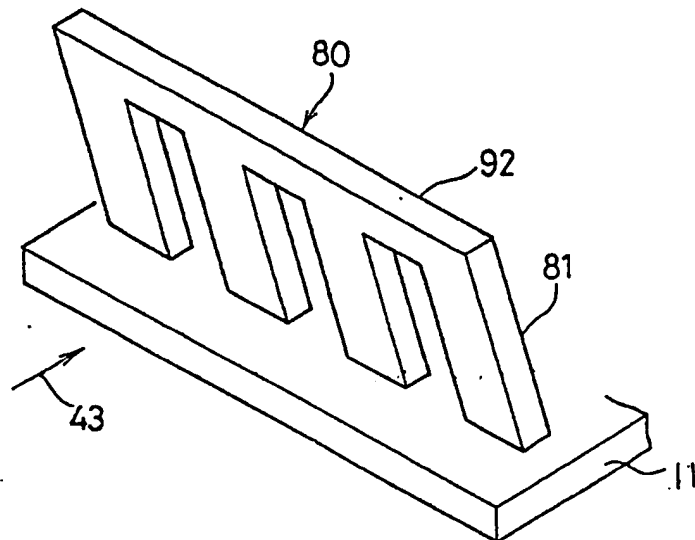


FIG. 12A

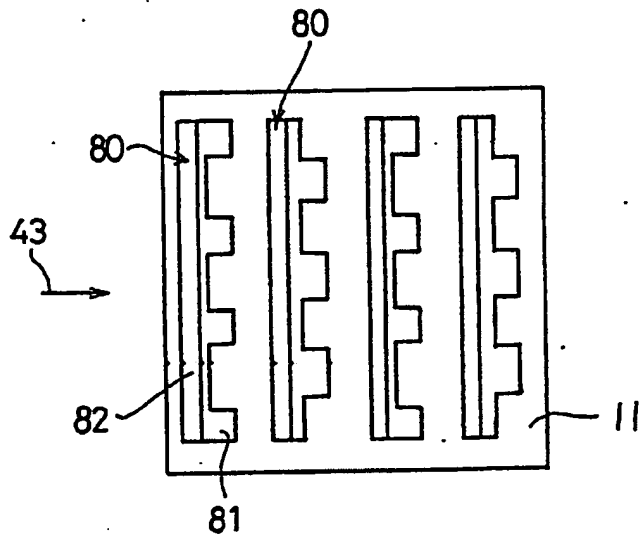


FIG. 12B

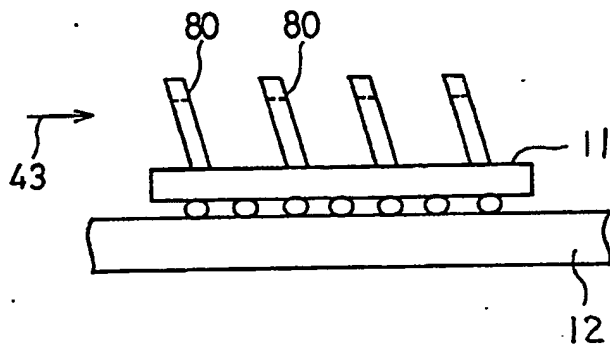




FIG. 13

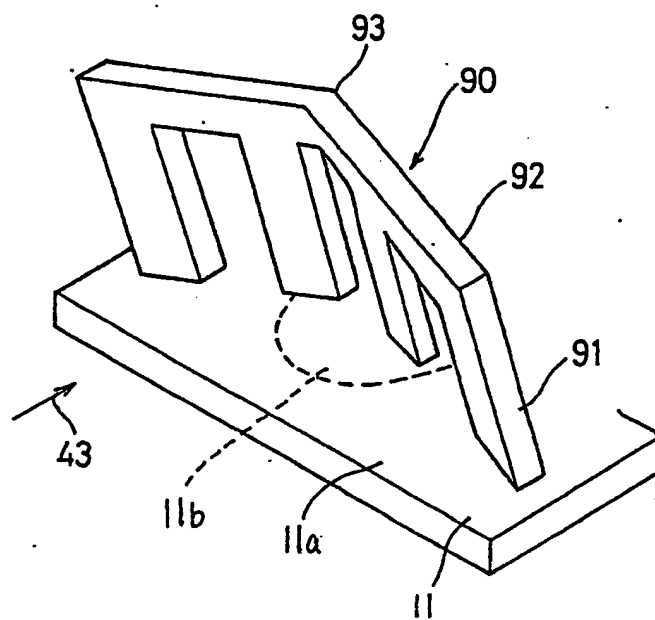


FIG. 14A

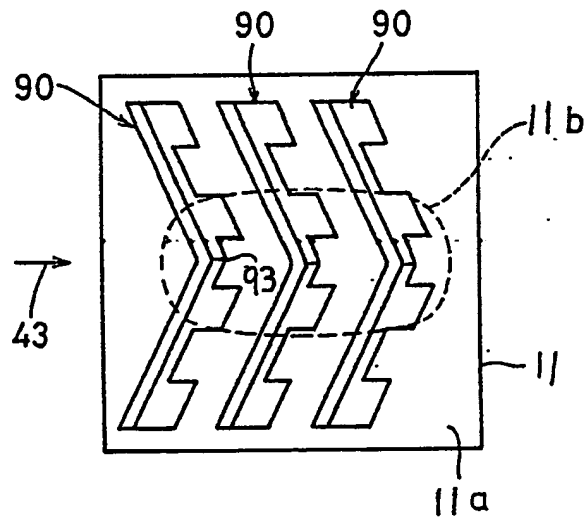


FIG. 14B

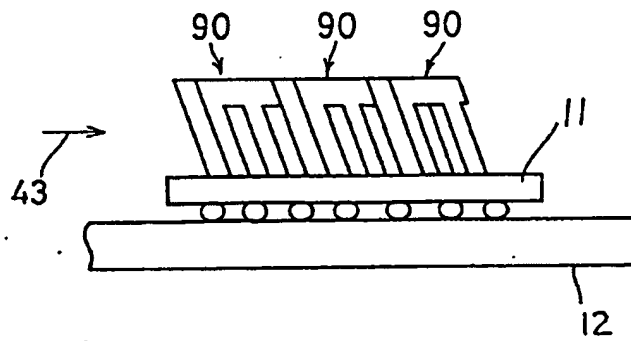


FIG. 15A

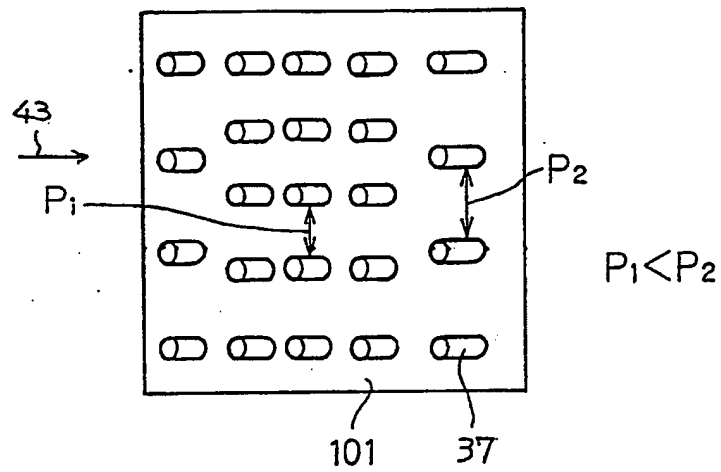


FIG. 15B

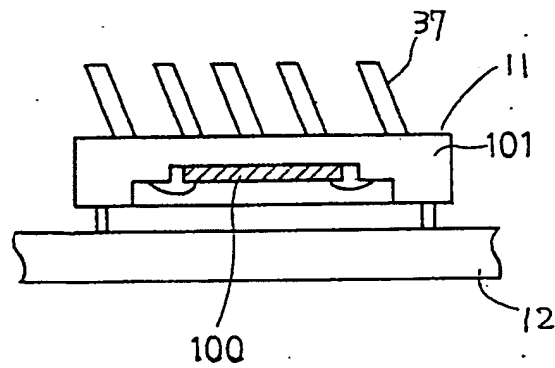
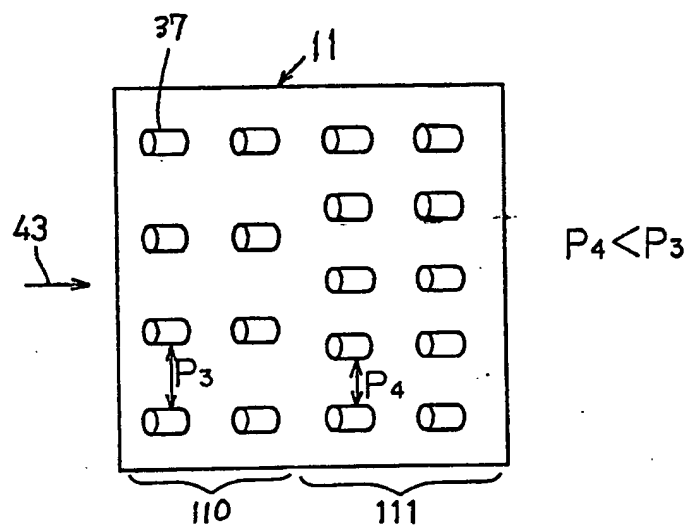


FIG. 16



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FIG. 17

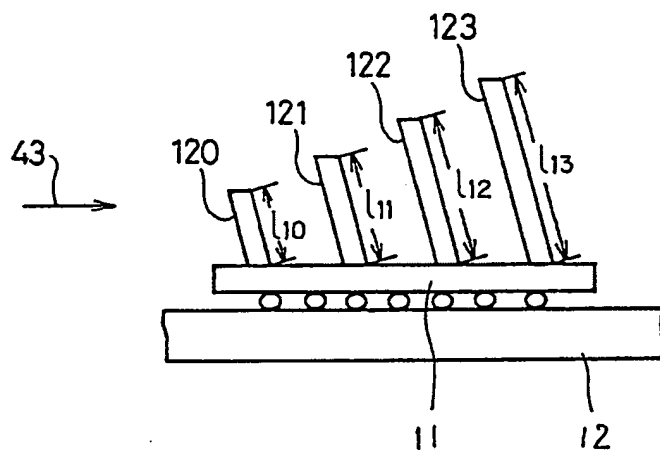


FIG. 18

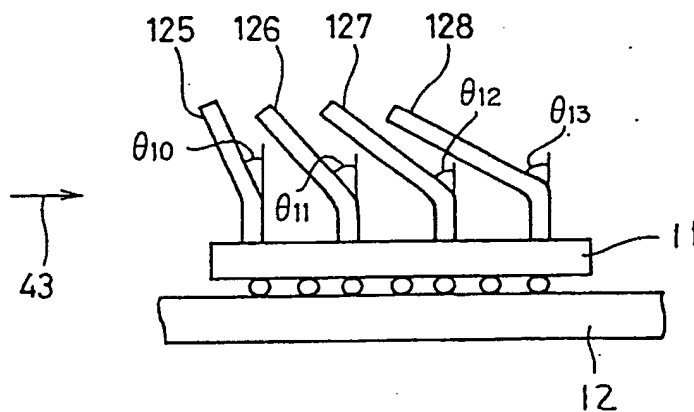




FIG. 20

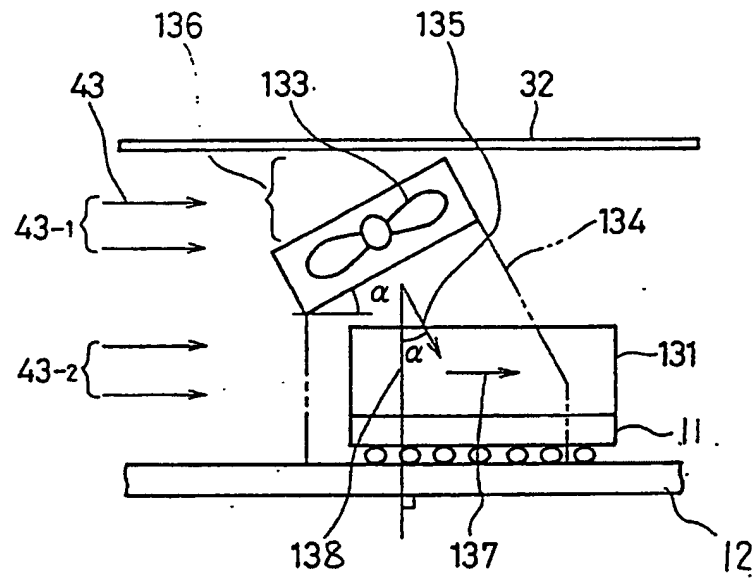


FIG. 21

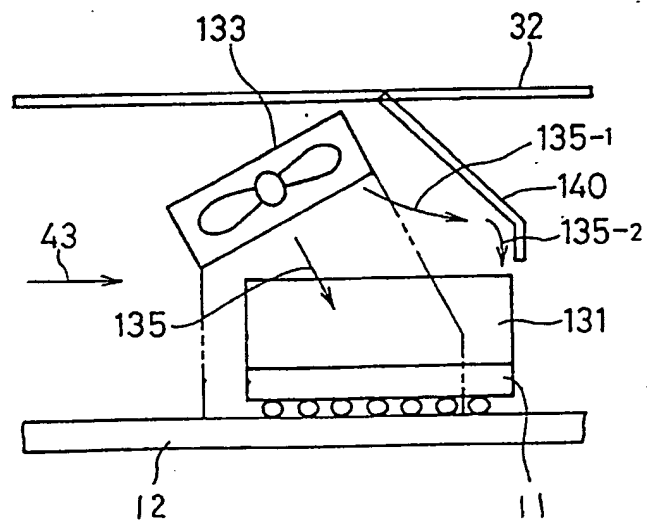


FIG. 22

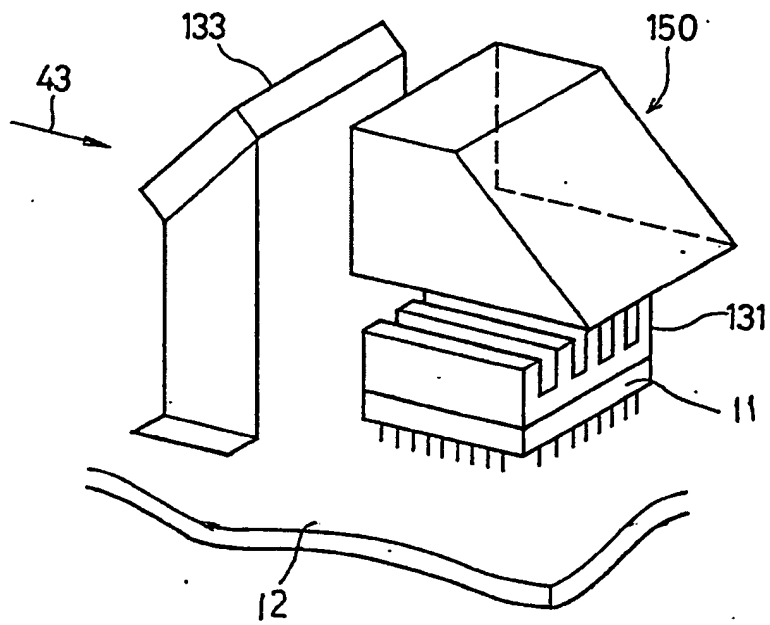


FIG. 23

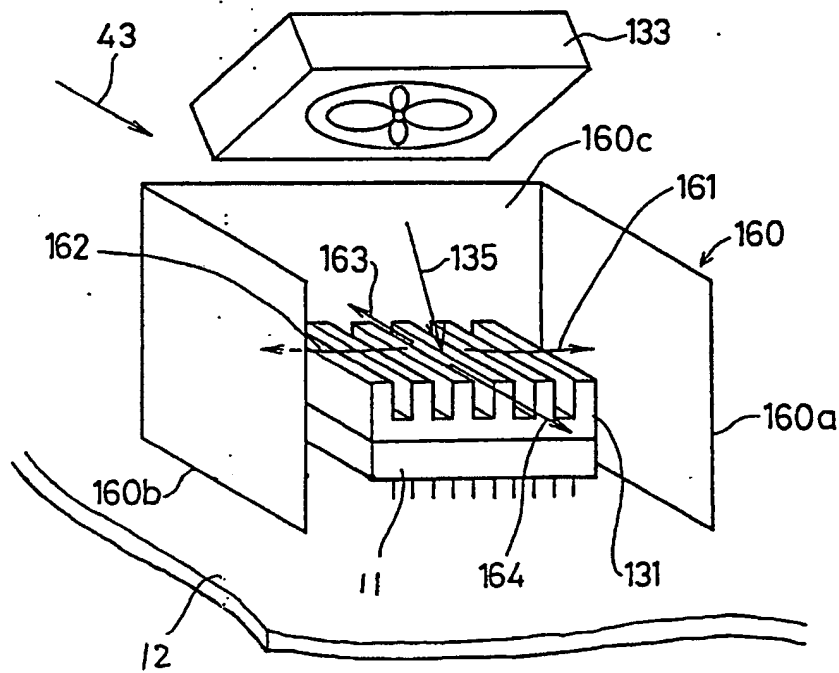




FIG. 24

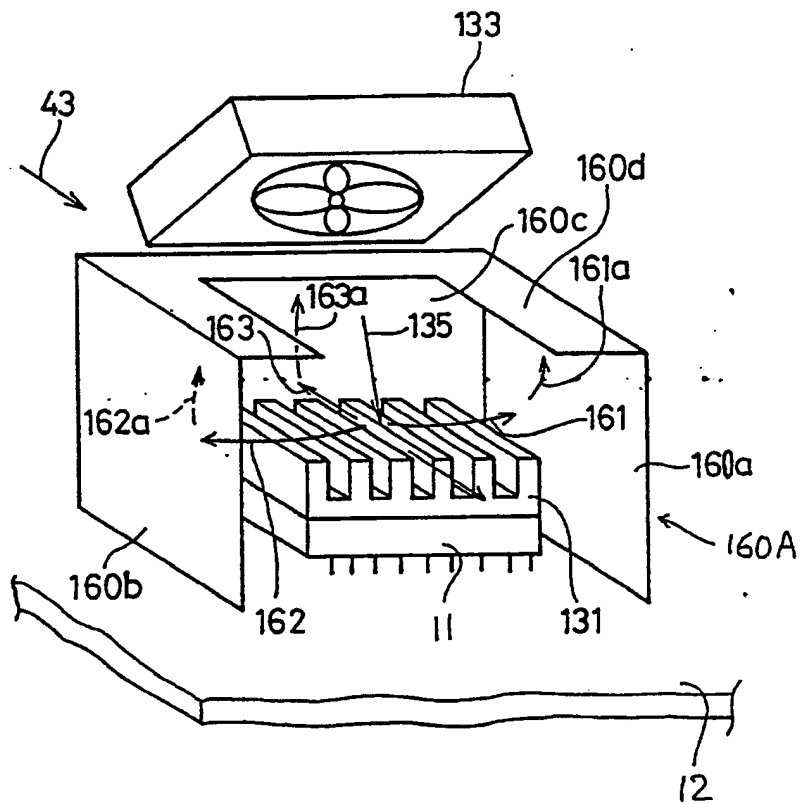




FIG. 26

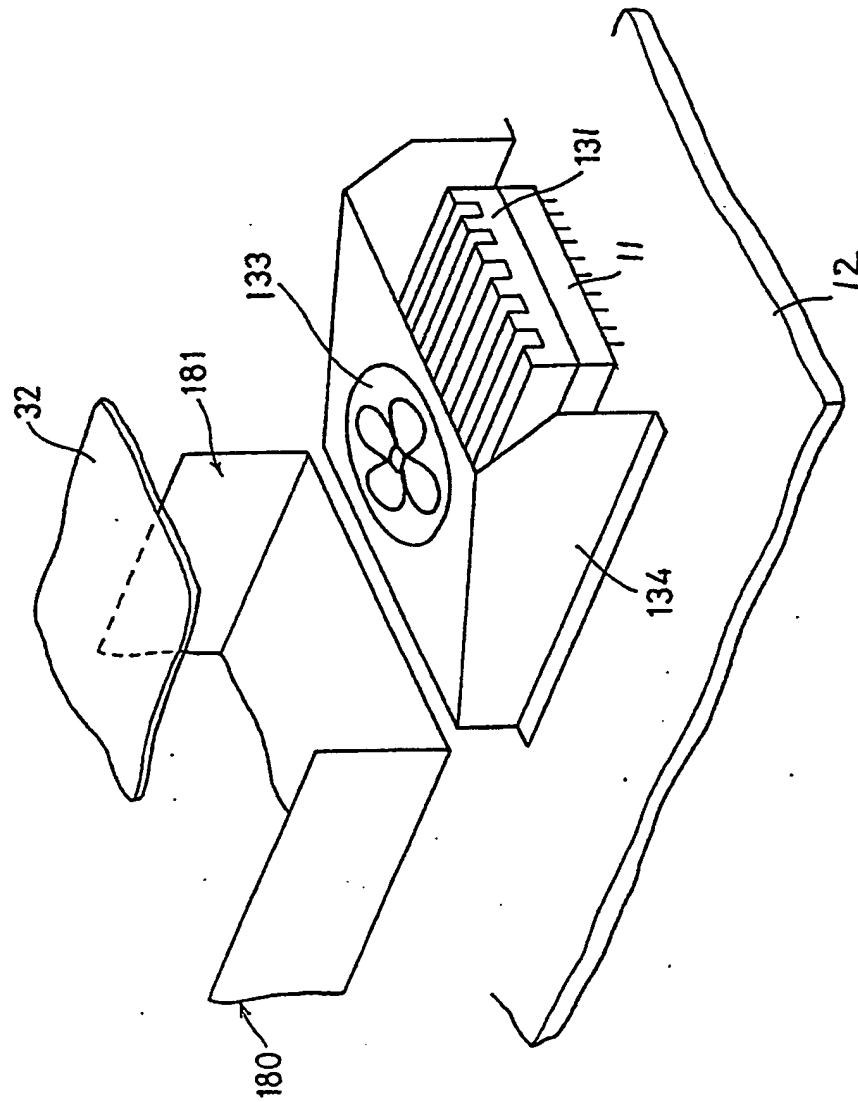


FIG. 27

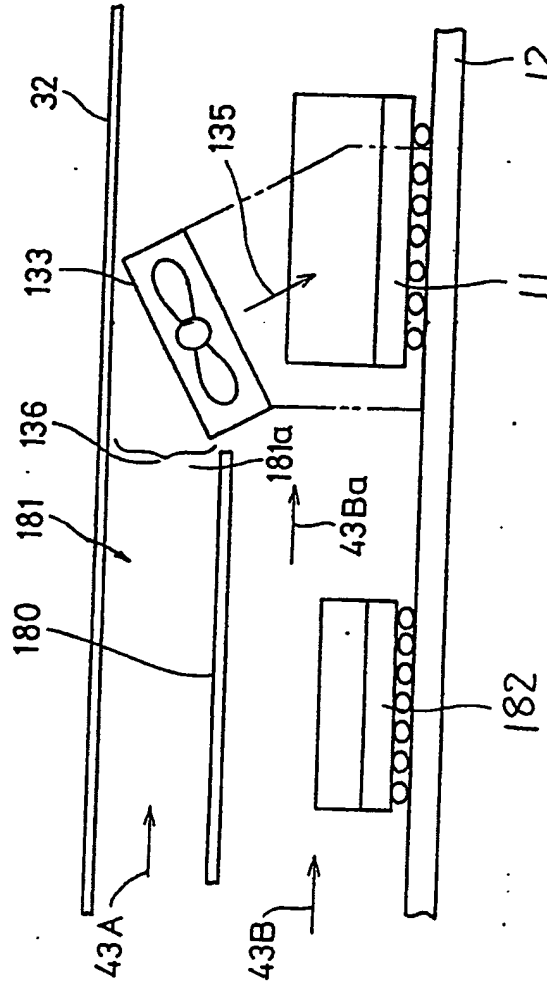


FIG. 28

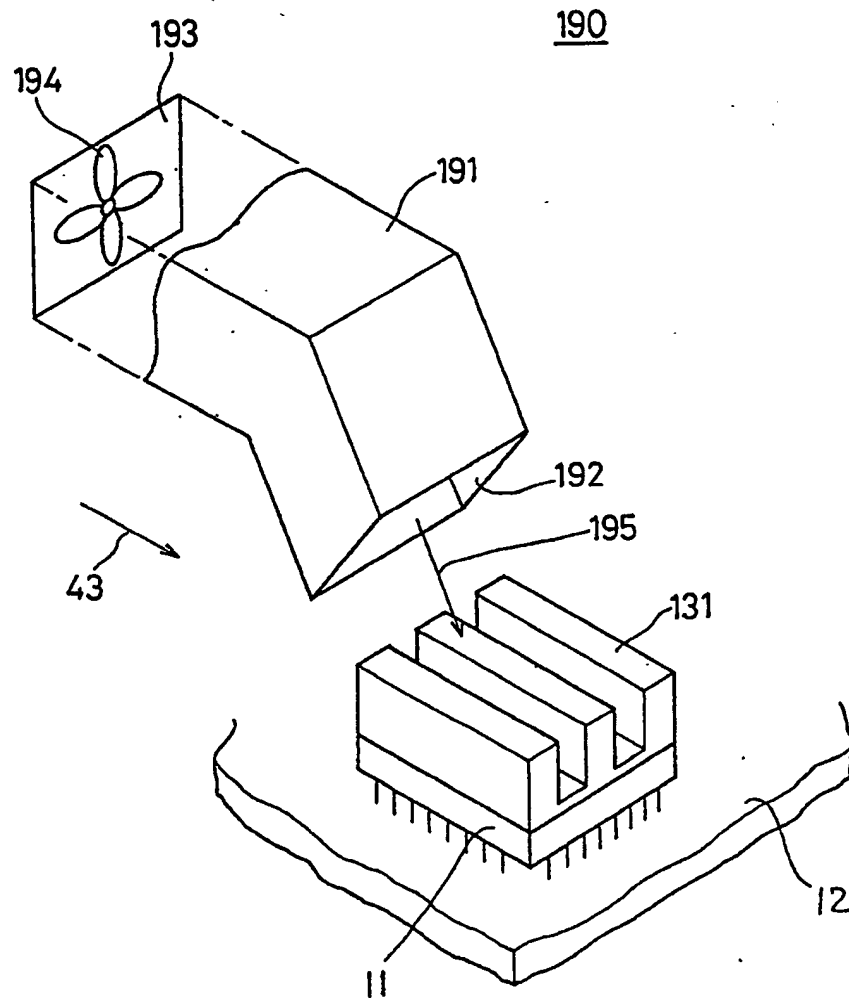


FIG. 29

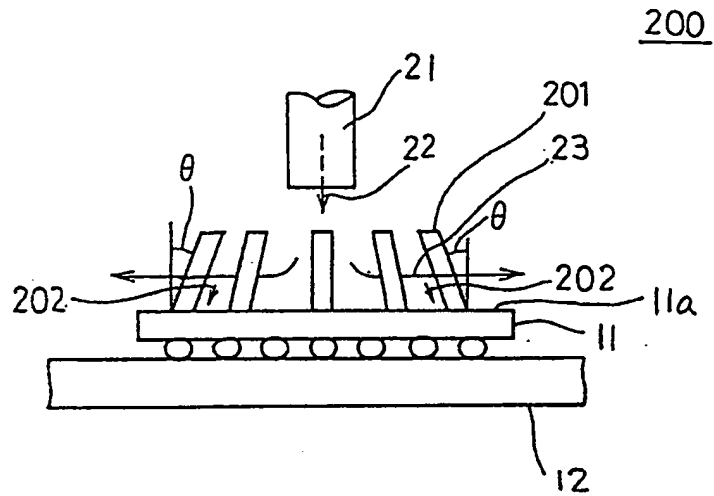


FIG. 30

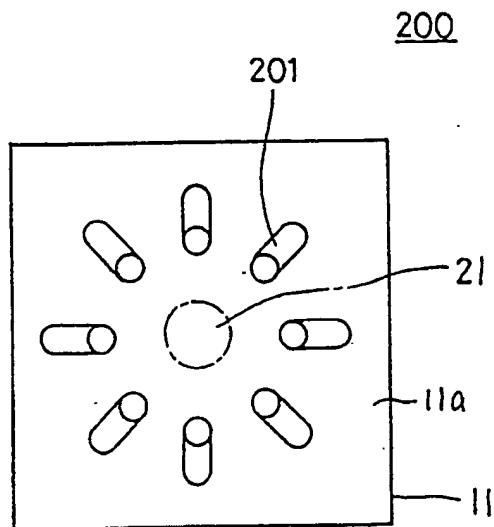








FIG. 34

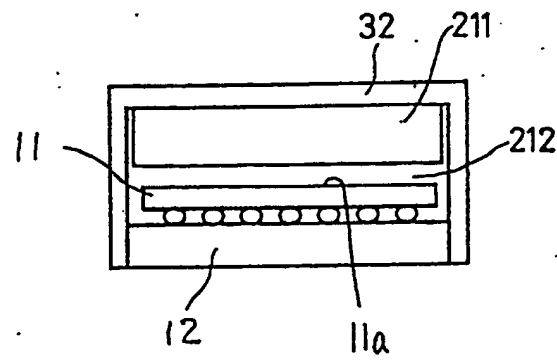


FIG. 35

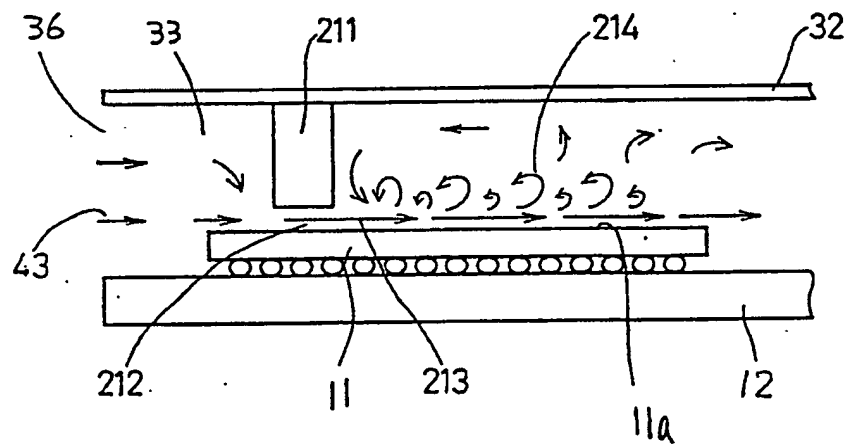


FIG. 36

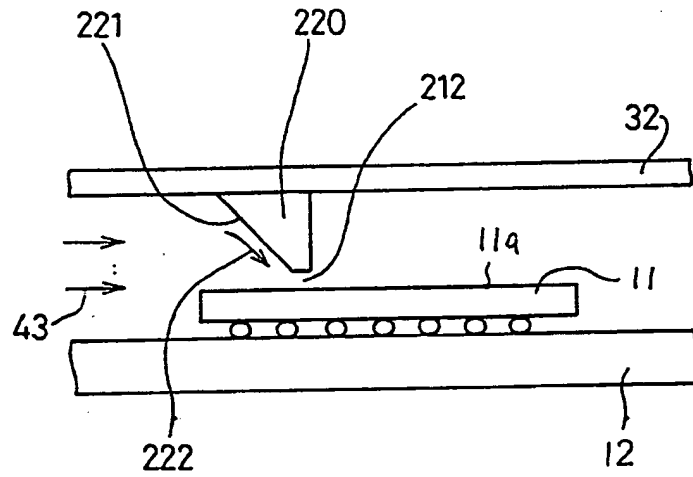


FIG. 38

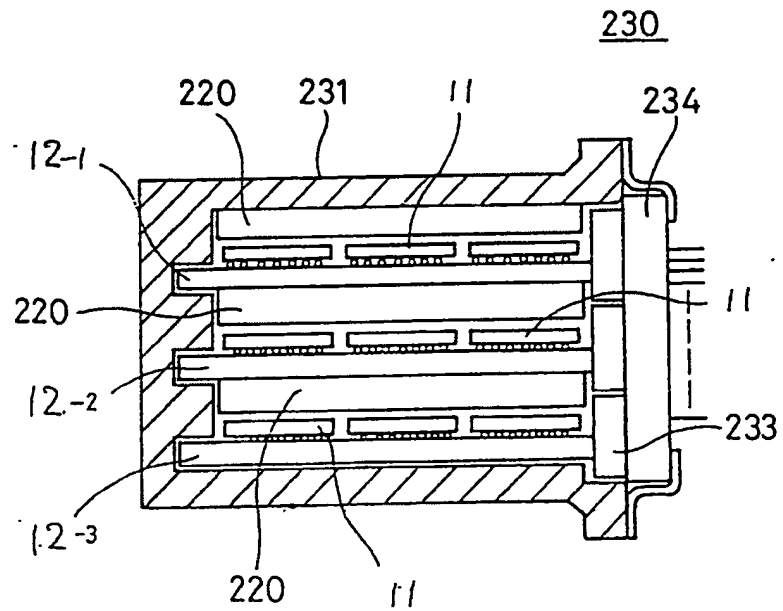


FIG. 37

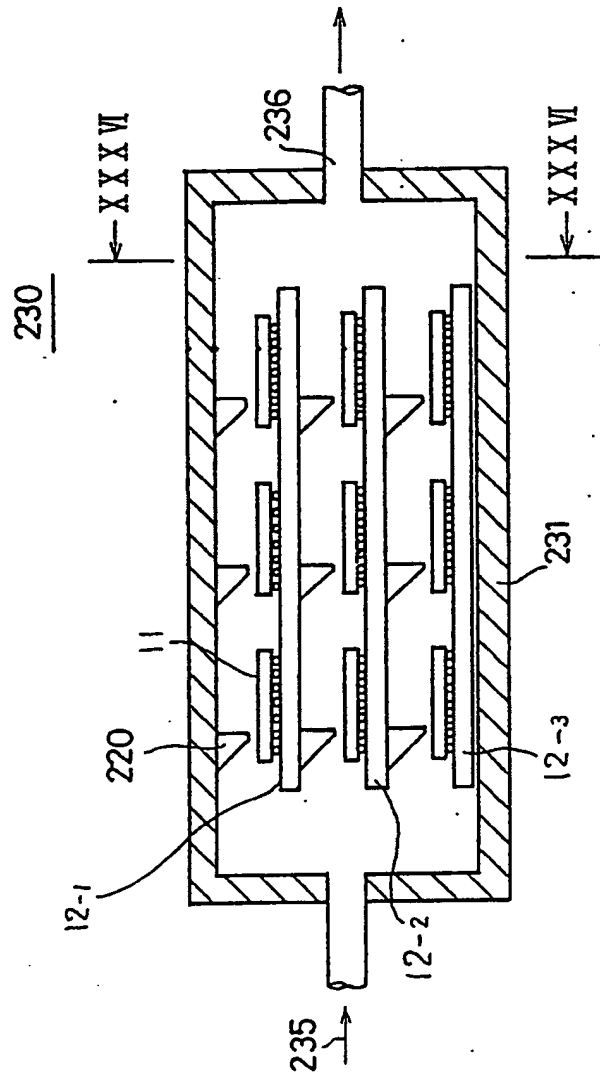


FIG. 39

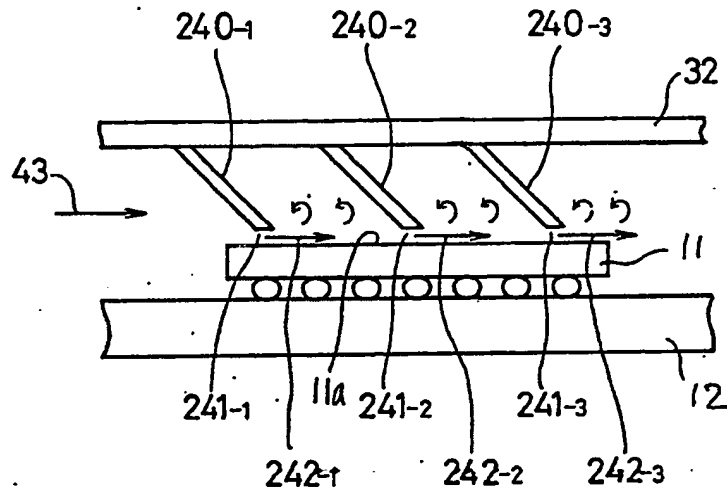


FIG. 40

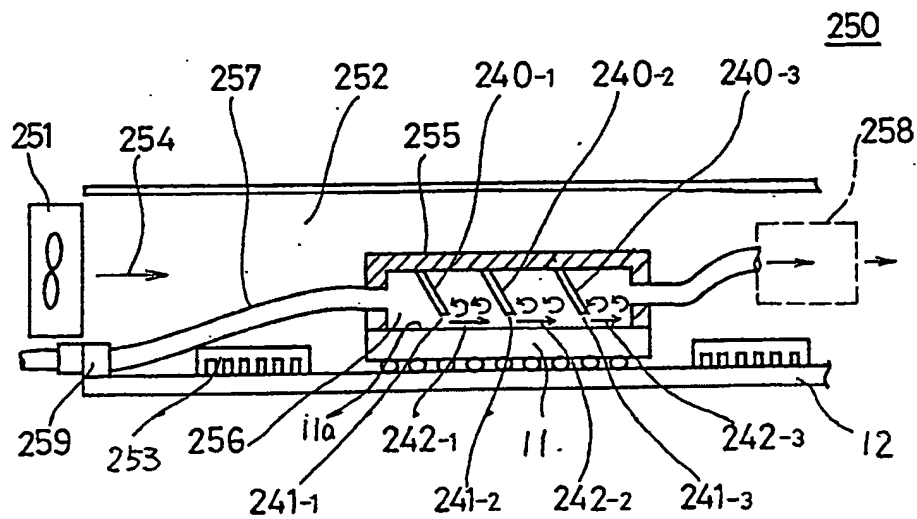


FIG. 41

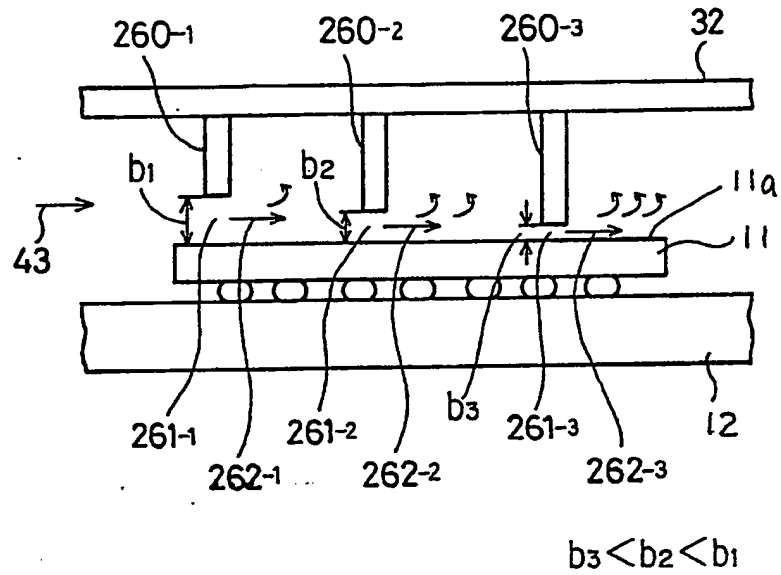


FIG. 42

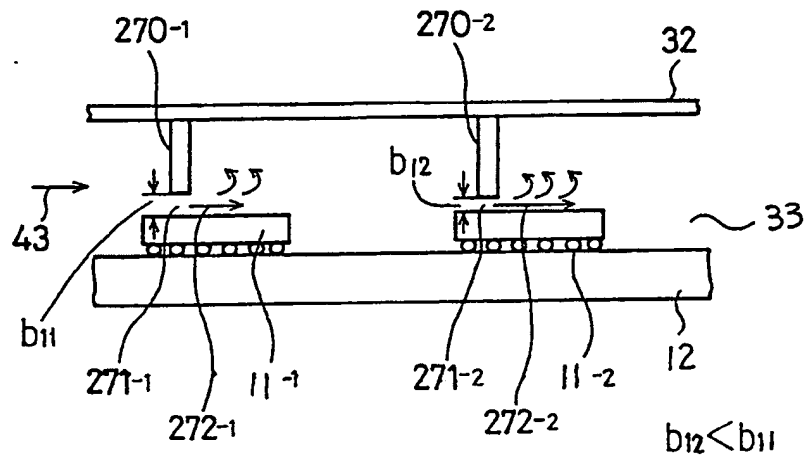


FIG. 43

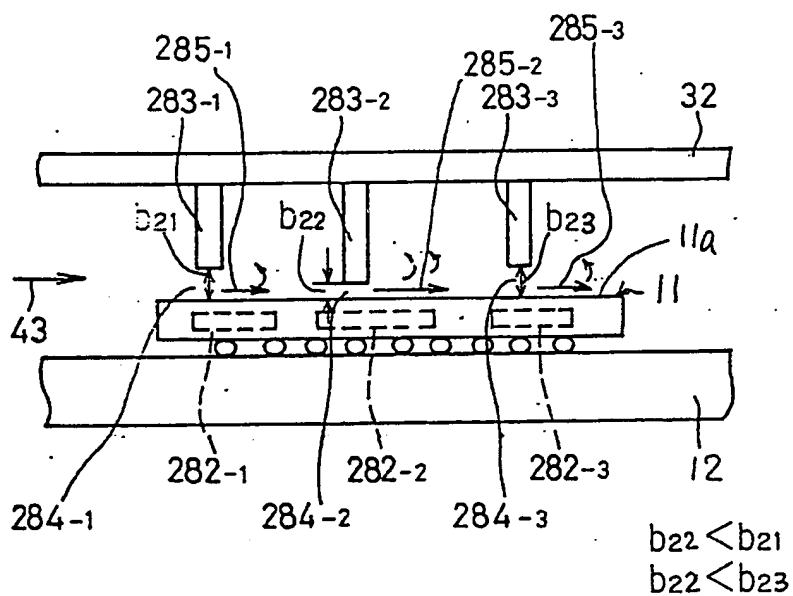


FIG. 44

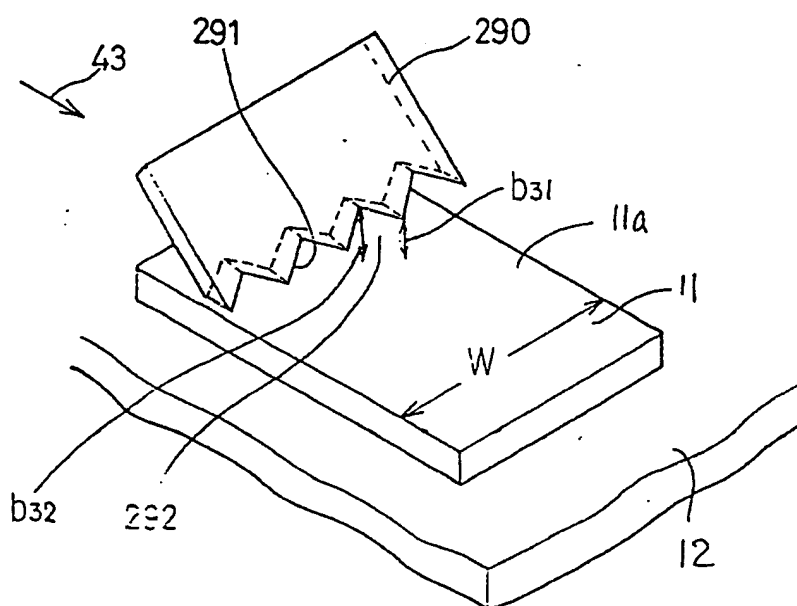


FIG. 45

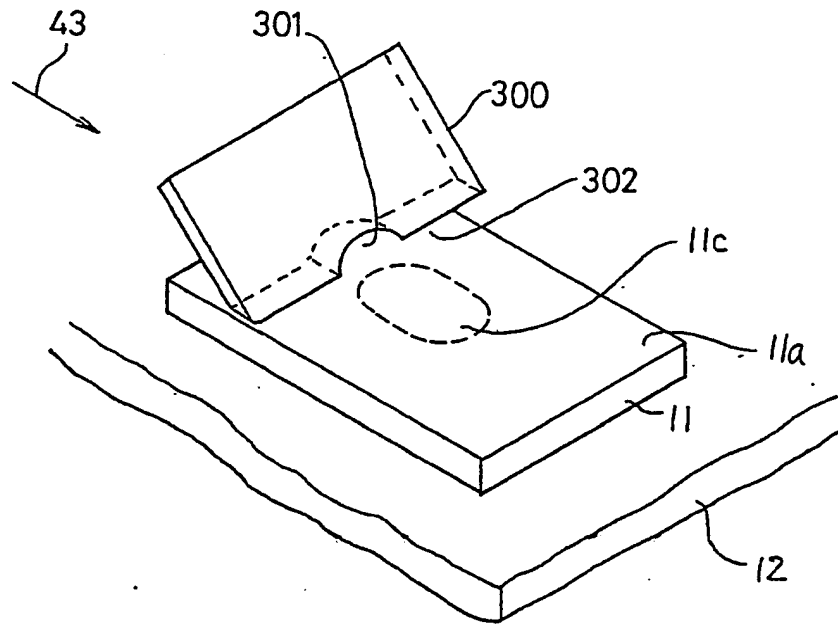


FIG. 46

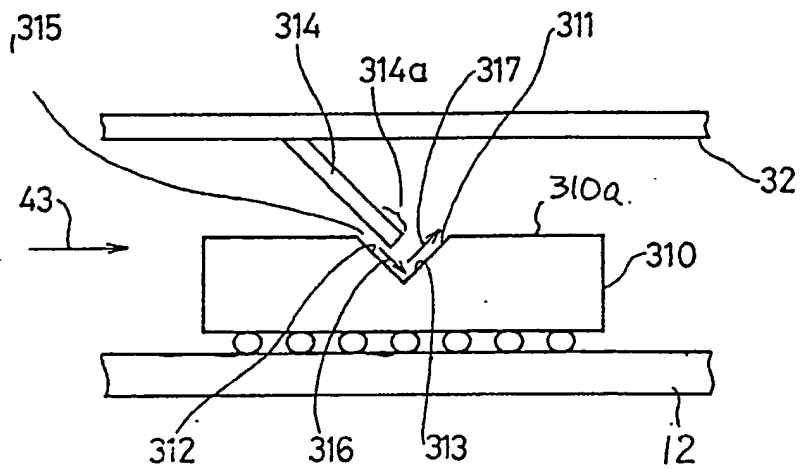


FIG. 47

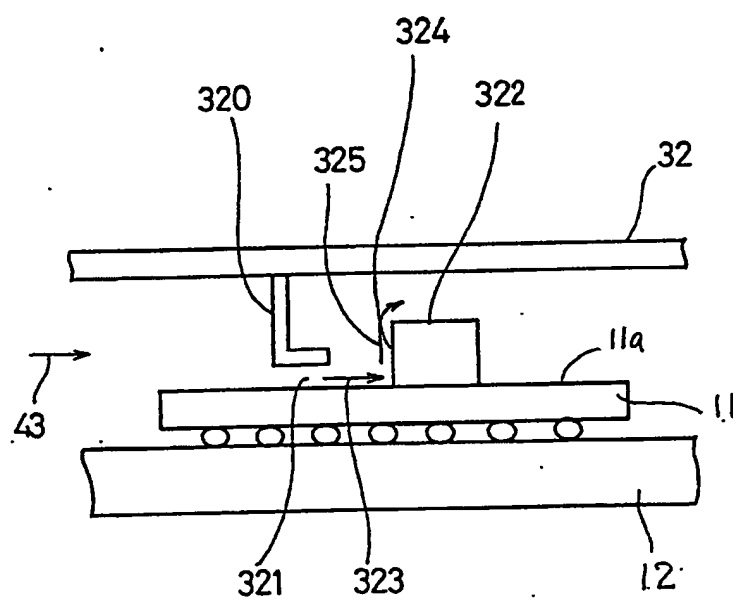




FIG. 48A

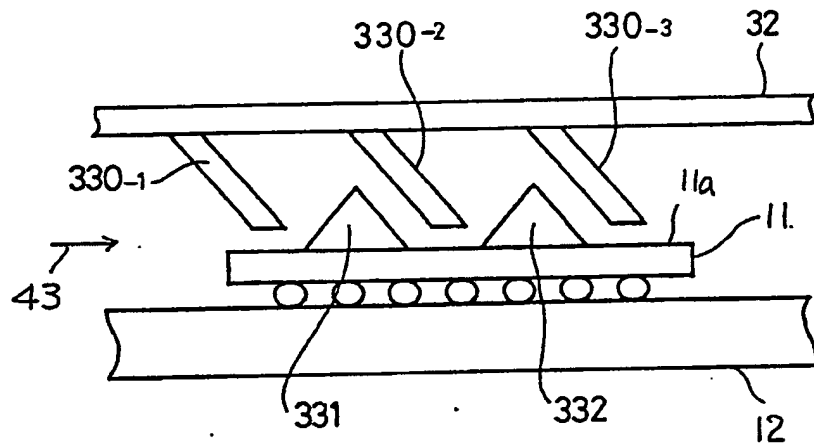


FIG. 48B

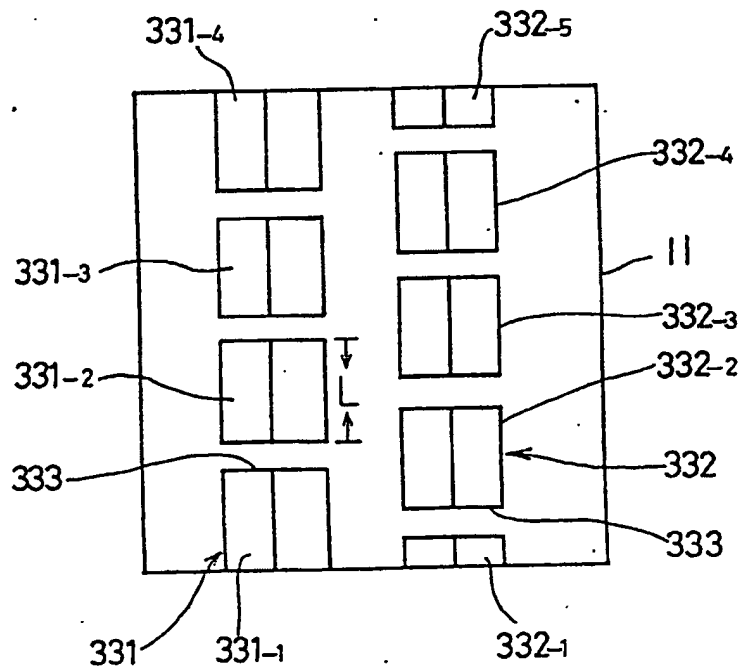


FIG. 49

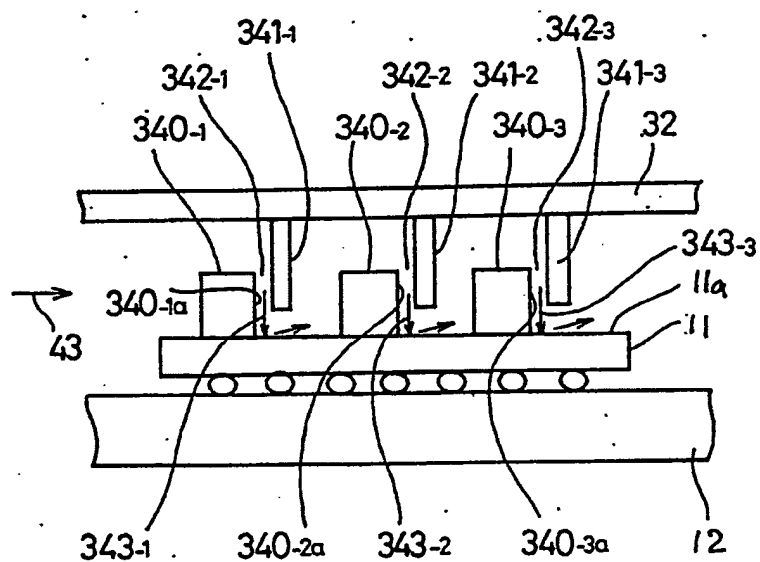


FIG. 50

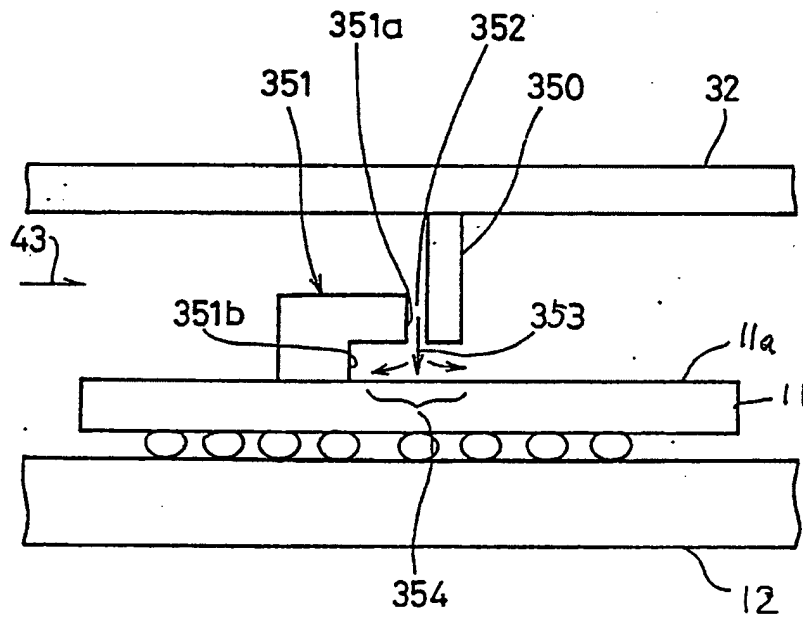


FIG. 51A

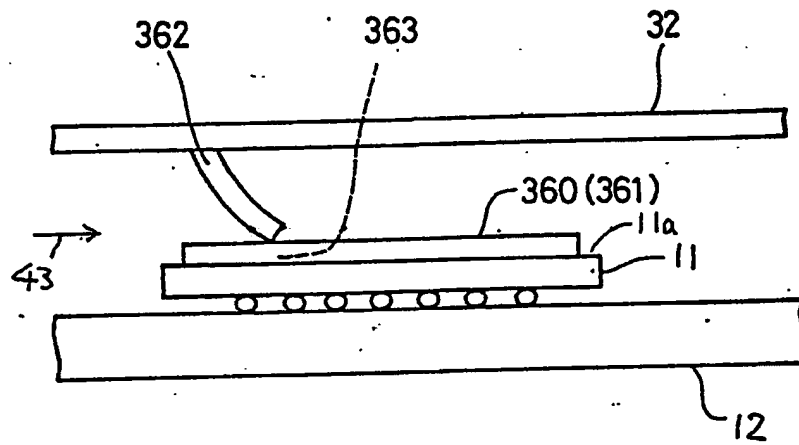


FIG. 51B

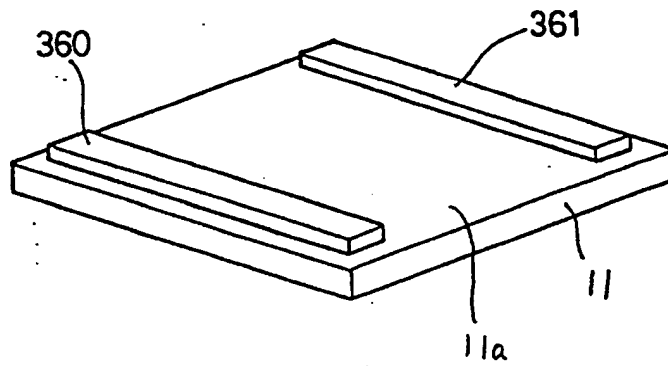


FIG. 52A

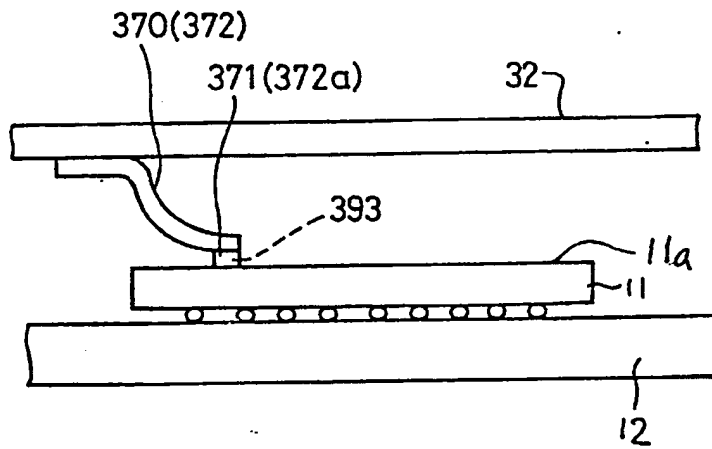


FIG. 52B

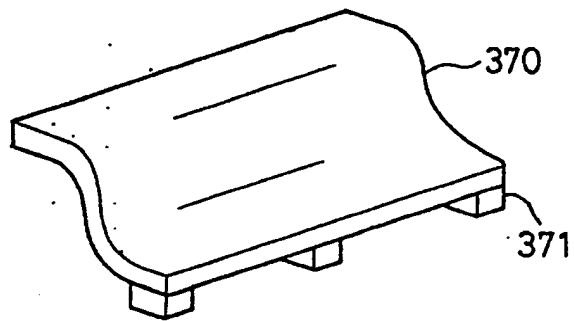
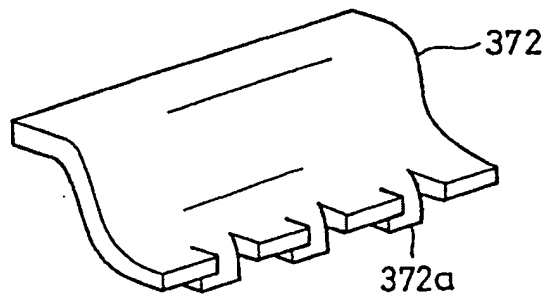


FIG. 52C



1                   "SEMICONDUCTOR ELEMENT COOLING APPARATUS"

                  The present invention generally relates to  
semiconductor element cooling apparatuses, and more  
5       particularly to a semiconductor cooling apparatus for  
cooling semiconductor elements which are mounted on a  
circuit substrate and assembled within an electronic  
equipment.

                  Recently, the heat generated by the  
10       semiconductor element has increased due to the improved  
integration density and the high-speed operation of the  
integrated circuit. This tendency is particularly  
notable in the field of large scale integrated circuits  
(LSIs) which are used in computers and the like. For  
15       example, on the chip level, it is not rare that heat on  
the order of 10 W is generated per 1 cm<sup>2</sup>, and it is  
expected that this value will be doubled or tripled in  
the near future.

                  On the other hand, the mounting density of  
20       the semiconductor elements within the electronic  
equipment is also rapidly increasing. Consequently, it  
is becoming more difficult to carry out the cooling  
within the electronic equipment.

                  Furthermore, in order to stably operate the  
25       semiconductor elements, it is essential to maintain the  
temperature of the semiconductor elements low, and a  
high cooling efficiency is required of the cooling  
apparatus.

                  FIG.1 shows a conceivable semiconductor  
30       element cooling apparatus 10. In FIG.1, semiconductor  
elements 11 are mounted on a circuit substrate 12 via a  
plurality of connecting members 13 such as solder. A  
plurality of pin-shaped fins 14 are fixed on a top  
surface 11a of the semiconductor element 11,  
35       perpendicularly to the top surface 11a.

                  The semiconductor element 11 is cooled when a  
coolant (cooling medium) 15 flows parallel to the

1 circuit substrate 12 and passes the periphery of the  
semiconductor element 11. In other words, the cooling  
takes place due to heat exchange between the coolant 15  
and the pin-shaped fins 14 and the top surface 11a of  
5 the semiconductor element 11.

On the other hand, FIG.2 shows another  
conceivable semiconductor element cooling apparatus 20.  
In FIG.2, the semiconductor element 11 is mounted on  
the circuit substrate 12, and a nozzle 21 is arranged  
10 above the semiconductor element 11, perpendicularly to  
the top surface 11a of the semiconductor element 11.

A high-speed coolant flow 22 ejected from the  
nozzle 21 at a high speed hits the top surface 11a of  
the semiconductor element 11, and thereafter forms a  
15 jet flow 23 which spreads radially along the top  
surface 11a, so as to cool the semiconductor element  
11. Such a cooling using the jet flow is advantageous  
in that a relatively high cooling efficiency can be  
obtained by employing a relatively simple construction.

20 According to the semiconductor element  
cooling apparatus 10 shown in FIG.1, it is necessary to  
increase the length of the pin-shaped fins 14 or to  
increase the number of the pin-shaped fins 14 per unit  
area on the top surface 11a of the semiconductor  
25 element 11. However, the former method of increasing  
the length of the pin-shaped fins 14 deteriorates the  
fin efficiency, and there is a limit to improving the  
cooling efficiency. On the other hand, the latter  
method of increasing the number of the pin-shaped fins  
30 14 per unit area increases the flow resistance, and the  
cooling efficiency is not as high as expected because  
the flow of the coolant is blocked at the lower parts  
of the pin-shaped fins 14 and at the top surface 11a of  
the semiconductor element 11.

35 On the other hand, according to the  
semiconductor element cooling apparatus 20 shown in  
FIG.2, a space having a height A is inevitably required

1 above the circuit substrate 12 because of the need to  
arrange the nozzle 21 so as to confront the top surface  
11a of the semiconductor element 11. As a result, it  
is difficult to accommodate the circuit substrate 12  
5 within the electronic equipment with a high density by  
arranging the circuit substrate 12 at a narrow pitch.

Accordingly, it is a general object of the  
present invention to provide a novel and useful  
semiconductor element cooling apparatus in which the  
10 problems described above are eliminated.

According to one aspect of the present  
invention, there is provided a semiconductor element  
cooling apparatus adapted to cool at least one  
semiconductor element mounted on a circuit substrate,  
15 said semiconductor element cooling apparatus comprising  
first means for generating a coolant flow by flowing a  
coolant over a top surface of the semiconductor  
element; and second means for obliquely hitting the  
coolant on the semiconductor element from an upstream  
20 side towards a downstream side of the coolant flow.  
According to the semiconductor element cooling  
apparatus of the present invention, the coolant flow  
efficiently absorbs the heat from the top surface of  
the semiconductor element, and the cooling efficiency  
25 is improved.

Still another object of the present invention  
is to provide the semiconductor element cooling  
apparatus described first above, wherein the second  
means comprises a plurality of inclined pillar-shaped  
30 radiator fins provided on the top surface of the  
semiconductor element and respectively having a portion  
which is inclined to the upstream side of the coolant  
flow. According to the semiconductor element cooling  
apparatus of the present invention, the cooling  
35 efficiency is improved at the lower part of the  
inclined pillar-shaped radiator fins towards the top  
surface of the semiconductor element, and the surface



1 area of the inclined pillar-shaped radiator fins is  
increased. For this reason, it is possible to improve  
the cooling efficiency of the semiconductor element.

5 A further object of the present invention is  
to provide the semiconductor element cooling apparatus  
described second above, wherein the second means  
further comprises a comb shaped structure connecting  
top ends of the inclined pillar-shaped radiator fins  
which are arranged in a direction generally  
10 perpendicular to a direction of the coolant flow.  
According to the semiconductor element cooling  
apparatus of the present invention, it is possible to  
manufacture the plurality of inclined pillar-shaped  
radiator fins in one process, and the productivity is  
15 greatly improved.

Another object of the present invention is to  
provide the semiconductor element cooling apparatus  
described first above, wherein the first means  
comprises a passage forming member forming a passage  
20 between the passage forming member and the top surface  
of the semiconductor element, and a coolant driving  
unit for supplying the coolant to the passage so as to  
form a parallel coolant flow within the passage, the  
parallel coolant flow being approximately parallel to  
25 the top surface of the semiconductor element, and the  
second means comprises a fan which is provided at a  
position confronting the semiconductor element and is  
inclined with respect to the top surface of the  
semiconductor element. According to the semiconductor  
30 element cooling apparatus of the present invention, the  
fan generates a jet flow of the coolant having a large  
flow quantity. For this reason, it is possible to  
increase the flow quantity of the coolant obliquely  
hitting the top surface of the semiconductor element,  
35 and accordingly cool the semiconductor element with a  
high cooling efficiency.

Still another object of the present invention

1    ~~is to provide the semiconductor element cooling~~  
apparatus described fourth above, which further  
comprises third means, provided on a periphery of the  
fan, for restricting the coolant ejected from the fan  
5    from moving around to a draw-in side of the fan.  
According to the semiconductor element cooling  
apparatus of the present invention, it is possible to  
prevent the coolant ejected from the fan from moving  
around to the draw-in side of the fan, and thus prevent  
10    the temperature of the coolant from rising thereby. In  
other words, the coolant ejected from the fan can  
always be maintained to a low temperature, and it is  
therefore possible to stably cool the semiconductor  
element.

15            A further object of the present invention is  
to provide the semiconductor element cooling apparatus  
described first above, wherein the first means  
comprises a passage forming member forming a passage  
between the passage forming member and the top surface  
20    of the semiconductor element, and a coolant driving  
unit for supplying the coolant to the passage so as to  
form a parallel coolant flow within the passage, the  
parallel coolant flow being approximately parallel to  
the top surface of the semiconductor element, and the  
25    second means comprises a duct having a tip end which  
confronts the semiconductor element and is inclined  
with respect to the top surface of the semiconductor  
element, and a fan ejecting the coolant from the duct.  
According to the semiconductor element cooling  
30    apparatus of the present invention, it is possible to  
form a jet flow of the coolant having a large flow  
quantity. For this reason, the flow quantity of the  
coolant hitting the top surface of the semiconductor  
element can be increased, thereby enabling the  
35    semiconductor element to be cooled with a high cooling  
efficiency.

            According to another aspect of the present

1 invention, there is provided a semiconductor element  
cooling apparatus adapted to cool at least one  
semiconductor element mounted on a circuit substrate,  
said semiconductor element cooling apparatus comprising  
5 a passage forming member forming a passage between said  
passage forming member and a top surface of the  
semiconductor element; a coolant driving unit supplying  
a coolant to the passage so as to form a parallel  
coolant flow above the top surface of the semiconductor  
10 element, said parallel coolant flow being approximately  
parallel to the top surface of the semiconductor  
element; and one or a plurality of partition members  
provided on a surface of said passage forming member  
confronting the top surface of the semiconductor  
15 element, each of said partition members having a base  
part which extends in a direction generally  
perpendicular to the parallel coolant flow, and a tip  
part which forms a slit-shaped coolant outlet having a  
predetermined gap between the tip part and the top  
20 surface of the semiconductor element. According to the  
semiconductor element cooling apparatus of the present  
invention, it is unnecessary to use a nozzle as in the  
conceivable case. It is possible to utilize the high  
cooling efficiency of the jet flow of the coolant, and  
25 at the same time, enable the circuit substrates and  
thus the semiconductor elements to be mounted within  
the electronic equipment with a high mounting density.

Still another object of the present invention  
is to provide the semiconductor element cooling  
30 apparatus described seventh above, which further  
comprises one or a plurality of surfaces provided on  
the top surface of the semiconductor element, where the  
coolant ejected from the slit-shaped coolant outlet  
hits the one or plurality of surfaces. According to  
35 the semiconductor element cooling apparatus of the  
present invention, it is possible to rapidly change the  
direction of the coolant flow by collision, and thus

1     improve the cooling efficiency of the semiconductor  
element.

5     A further object of the present invention is  
to provide the semiconductor element cooling apparatus  
described seventh above, wherein the one or plurality  
of partition members structurally connect to the  
semiconductor element directly without via the circuit  
substrate. According to the semiconductor element  
cooling apparatus of the present invention, the  
10    partition member and the passage forming member can be  
connected to the semiconductor element without via the  
circuit substrate. As a result, the assembling process  
is facilitated, and the cooling performance is  
stabilized.

15    Other objects and further features of the  
present invention will be apparent from the following  
detailed description when read in conjunction with the  
accompanying drawings.

20    FIG.1 is a side view showing a conceivable  
semiconductor element cooling apparatus;

FIG.2 is a side view showing another  
conceivable semiconductor element cooling apparatus;

25    FIG.3 is a perspective view, with a part cut  
away, showing a first embodiment of a semiconductor  
element cooling apparatus according to the present  
invention;

FIG.4 is a plan view showing a semiconductor  
element shown in FIG.3;

30    FIG.5 is a side view showing a part of the  
semiconductor element shown in FIG.3;

FIG.6 is a perspective view for explaining  
the functions of an inclined columnar radiator fin;

FIG.7 is a perspective view showing a first  
modification of a radiator fin shown in FIG.3;

35    FIG.8 is a perspective view showing a second  
modification of the radiator fin shown in FIG.3;

FIG.9 is a perspective view showing a third

1       modification of the radiator fin shown in FIG.3;

FIG.10 is a perspective view showing a fourth  
modification of the radiator fin shown in FIG.3;

5       FIG.11 is a perspective view showing a fifth  
modification of the radiator fin shown in FIG.3;

FIGS.12A and 12B respectively are a plan view  
and a side view showing the radiator fin shown in  
FIG.11 in the mounted state;

10       FIG.13 is a perspective view showing a sixth  
modification of the radiator fin shown in FIG.3;

FIGS.14A and 14B respectively are a plan view  
and a side view showing the radiator fin shown in  
FIG.13 in the mounted state;

15       FIGS.15A and 15B respectively are a plan view  
and a side view showing a first modification of the  
arrangement of the inclined columnar radiator fins;

FIG.16 is a plan view showing a second  
modification of the arrangement of the inclined  
columnar radiator fins;

20       FIG.17 is a side view showing the arrangement  
of inclined columnar radiator fins having different  
lengths;

25       FIG.18 is a side view showing the arrangement  
of inclined columnar radiator fins having different  
inclination angles;

FIG.19 is a perspective view, with a part cut  
away, showing a second embodiment of the semiconductor  
element cooling apparatus according to the present  
invention;

30       FIG.20 is a side view for explaining the  
relationship of a fan and a semiconductor element in  
FIG.19;

FIG.21 is a side view showing a first  
modification of the second embodiment;

35       FIG.22 is a perspective view showing a second  
modification of the second embodiment;

FIG.23 is a perspective view showing a third

1      modification of the second embodiment;

FIG.24 is a perspective view showing a fourth  
modification of the second embodiment;

5      FIG.25 is a perspective view showing a fifth  
modification of the second embodiment;

FIG.26 is a perspective view showing a sixth  
modification of the second embodiment;

FIG.27 is a side view showing the sixth  
modification shown in FIG.26;

10      FIG.28 is a perspective view showing a third  
embodiment of the semiconductor element cooling  
apparatus according to the present invention;

FIG.29 is a side view showing a fourth  
embodiment of the semiconductor element cooling  
15      apparatus according to the present invention;

FIG.30 is a plan view showing the fourth  
embodiment shown in FIG.29;

FIG.31 is a perspective view, with a part cut  
away, showing a fifth embodiment of the semiconductor  
20      element cooling apparatus according to the present  
invention;

FIG.32 is a plan view showing an important  
part of the fifth embodiment shown in FIG.31;

FIG.33 is a front view showing an important  
25      part of the fifth embodiment shown in FIG.31;

FIG.34 is a diagram showing the fifth  
embodiment shown in FIG.31 viewed from the direction of  
the flow of the coolant;

FIG.35 is a side view for explaining the  
30      operation of the fifth embodiment shown in FIG.31;

FIG.36 is a side view showing a first  
modification of the fifth embodiment;

FIG.37 is a cross sectional view showing a  
circuit substrate module applied with the first  
35      modification of the fifth embodiment shown in FIG.36;

FIG.38 is a cross sectional view along a line  
XXXVI-XXXVI in FIG.37;

1           FIG.39 is a side view showing a second  
modification of the fifth embodiment;

          FIG.40 is a cross sectional view showing an  
electronic equipment applied with the second  
5   modification of the fifth embodiment shown in FIG.39;

          FIG.41 is a side view showing a third  
modification of the fifth embodiment;

          FIG.42 is a side view showing a fourth  
modification of the fifth embodiment;

10          FIG.43 is a side view showing a fifth  
modification of the fifth embodiment;

          FIG.44 is a perspective view showing a sixth  
modification of the fifth embodiment;

          FIG.45 is a perspective view showing a  
15   seventh modification of the fifth embodiment;

          FIG.46 is a side view showing an eighth  
modification of the fifth embodiment;

          FIG.47 is a side view showing a ninth  
modification of the fifth embodiment;

20          FIGS.48A and 48B respectively are a side view  
and a plan view showing a tenth modification of the  
fifth embodiment;

          FIG.49 is a side view showing an eleventh  
modification of the fifth embodiment;

25          FIG.50 is a side view showing a twelfth  
modification of the fifth embodiment;

          FIGS.51A and 51B respectively are a side view  
and a perspective view showing a thirteenth  
modification of the fifth embodiment; and

30          FIGS.52A, 52B and 52C respectively are a side  
view, a perspective view and a perspective view showing  
a fourteenth modification of the fifth embodiment.

          FIG.3 shows a first embodiment of a  
semiconductor element cooling apparatus according to  
35   the present invention. In a semiconductor element  
cooling apparatus 30 shown in FIG.3, a circuit  
substrate 12 and a passage forming member 32 are

1 accommodated within a housing 31 of an electronic-  
equipment. A plurality of semiconductor elements 11  
are mounted on the circuit substrate 12. The passage  
forming member 32 is arranged parallel to the circuit  
5 substrate 12, and covers a top surface of the circuit  
substrate 12 on which the semiconductor elements 11 are  
mounted. The passage forming member 32 confronts the  
top surface of the circuit substrate 12 with a gap  
formed therebetween. A passage 33 having a height  $H_1$   
10 is formed between the circuit substrate 12 and the  
passage forming member 32. A fan 35 is coupled to one  
end of the passage 33 via a duct 34, as a coolant  
driving unit for ejecting a coolant (cooling medium).  
On the other hand, a coolant inlet 36 is provided on  
15 the other end of the passage 33.

When the fan 35 is driven, air 40 is drawn in  
from the coolant inlet 36 as the coolant. Hence, a  
parallel coolant flow 43 which is parallel to the  
circuit substrate 12 occurs within the passage 33 as  
20 indicated by an arrow.

As shown in FIGS. 4 and 5, a plurality of  
inclined pillar-shaped or columnar radiator fins 37 are  
provided on a top surface 11a of the semiconductor  
element 11 in a matrix arrangement. The inclined  
25 columnar radiator fins 37 are provided on the upstream  
side of the parallel coolant flow 43, that is, on the  
side of the coolant inlet 36. The inclined columnar  
radiator fins 37 are fixed with an inclination angle  $\theta$   
relative to a direction perpendicular to the top  
30 surface 11a of the semiconductor element 11. The  
inclined columnar radiator fins 37 themselves function  
as means for obliquely hitting the air 40.

During operation of the electronic equipment,  
the semiconductor element 11 generates heat. Majority  
35 of the generated heat spreads towards the inclined  
columnar radiator fins 37 due to thermal conduction.  
On the other hand, the fan 35 is also driven. Hence,



1 the generated parallel coolant flow 43 absorbs the heat  
from the inclined columnar radiator fins 37 and the top  
surface 11a of the semiconductor element 11 as the  
parallel coolant flow 43 passes the periphery of the  
5 semiconductor element 11. As a result, the  
semiconductor element 11 is cooled.

According to the semiconductor element  
cooling apparatus 30, the following effects are  
obtained because the inclined columnar radiator fins 37  
10 are inclined towards the upstream side at the  
inclination angle  $\theta$ , and the cooling efficiency with  
respect to the semiconductor element 11 is improved.

1) Stimulated coolant flow from lower part of  
fins towards the top surface of the semiconductor  
15 element:

As shown in FIG.6, the parallel coolant flow  
43 in the periphery of the inclined columnar radiator  
fin 37 is formed into a downwardly inclined flow 44  
along a front surface 38 of the inclined columnar  
20 radiator fin 37, and thereafter flows towards the  
downstream side by being divided into both sides of the  
inclined columnar radiator fin 37 as indicated by an  
arrow 45. For this reason, the rate of coolant flow  
from the lower part of the inclined columnar radiator  
25 fin 37 towards a fin base periphery 39 at the top  
surface 11a increases, and it is possible to  
efficiently carry out the cooling at this part.

2) Enlarged surface area of the columnar  
radiator fin:

30 As shown in FIG.5, with respect to the same  
height  $L_2$  of the columnar radiator fin, the length of  
the columnar radiator fin is  $L_2$  when the columnar  
radiator fin is not inclined, but the length of the  
columnar radiator fin is  $L_1$  when the columnar radiator  
35 fin is inclined by the inclination angle  $\theta$ .  $L_1$  is  
equal to  $L_2/\cos\theta$ , and thus, the length  $L_1$  becomes  
greater than the length  $L_2$  as the inclination angle  $\theta$

1 increases. Since the height of the columnar radiator  
fin is restricted by the height  $H_1$  of the passage 33,  
it is possible to increase the length of the columnar  
radiator fin and also increase the surface area of the  
5 columnar radiator fin compared to those of the  
conceivable semiconductor element cooling apparatus by  
inclining the columnar radiator fin as in the case of  
the inclined columnar radiator fin 37. For this  
reason, the heat quantity transferred from the inclined  
10 columnar radiator fin 37 to the parallel coolant flow  
43 is increased compared to that of the conceivable  
semiconductor element cooling apparatus.

In this embodiment, no particular limit is  
provided with respect to the inclination angle  $\theta$  of the  
15 inclined columnar radiator fin 37. However, the above  
described effects cannot be obtained to a satisfactory  
extent if the inclination angle  $\theta$  is too small. On the  
other hand, if the inclination angle  $\theta$  is too large,  
the tip end of the inclined columnar radiator fin 37  
20 greatly projects to the front and interferes with the  
mounting of the adjacent semiconductor element.  
Furthermore, the gap between the adjacent inclined  
columnar radiator fins 37 becomes small and interferes  
with the proper coolant flow. In other words, the  
25 superior cooling effect of the inclined columnar  
radiator fin 37 itself is lost if the inclination angle  
 $\theta$  is too large. Accordingly, from the practical point  
of view, it is desirable that the inclination angle  $\theta$   
is in a range of  $10^\circ$  to  $60^\circ$ .

30 The cross sectional shape of the inclined  
columnar radiator fin 37 is not limited to the  
rectangular shape of this embodiment. Similar effects  
can be obtained by using inclined columnar radiator  
fins having other cross sectional shapes such as a  
35 circular shape.

In addition, the semiconductor element 11 to  
be cooled is not limited to the bear-chip type shown in

1 FIG.3. For example, the semiconductor element 11 may  
be provided within a package or take the form of a  
multi-chip module.

Furthermore, the coolant is not limited to  
5 air, and other gasses and liquids may be used instead.  
For example, a liquid such as carbon fluoride may be  
used as the coolant. In this case, a pump is used as  
the coolant driving unit in place of the fan.  
Moreover, a tank for supplying and recovering the  
10 coolant, piping and a heat exchanger for cooling the  
coolant may be provided if necessary. It is of course  
possible to circulate the coolant among the tank, the  
pump, the heat exchanger and the passage 33.

The surface of the passage forming member 32  
15 confronting the circuit substrate 12 may be formed by  
the bottom surface of another circuit substrate which  
is accommodated in parallel to and adjacent to the  
circuit substrate 12. The bottom surface of this other  
circuit substrate is opposite to the surface on which  
20 the semiconductor elements are mounted. In addition,  
the surface of the passage forming member 32  
intersecting the circuit substrate 12 may be formed by  
the surface of another substrate such as a mother board  
connecting to the circuit substrate 12, the surface of  
25 a part such as a connector provided on the circuit  
substrate 12 and facing upstream side of the parallel  
coolant flow 43 and the like.

Next, a description will be given of  
modifications of the inclined columnar radiator fin 37  
30 of the first embodiment.

FIG.7 shows a first modification of the  
inclined columnar radiator fin. An inclined columnar  
radiator fin 60 show in FIG.7 has an approximately  
semi-circular cross section. The inclined columnar  
35 radiator fin 60 is arranged so that a flat surface 61  
thereof faces the upstream side of the parallel coolant  
flow 43.

1           According to the shape of this first  
modification of the inclined columnar radiator fin, the  
resistance with respect to the parallel coolant flow 43  
in a vicinity of the front surface of the inclined  
5   columnar radiator fin 60 is large. For this reason, it  
is possible to generate a stronger downwardly inclined  
flow 44 than the first embodiment, thereby contributing  
to an improved cooling efficiency.

FIG.8 shows a second modification of the  
10   inclined columnar radiator fin. An inclined columnar  
radiator fin 65 shown in FIG.8 has a crescent moon  
shaped cross section. The inclined columnar radiator  
fin 65 is arranged so that a concave surface 66 thereof  
faces the upstream side of the parallel coolant flow  
15   43.

According to the shape of this second  
modification of the inclined columnar radiator fin, it  
is possible to generate a stronger downwardly inclined  
flow 44 similarly to the first modification, thereby  
20   contributing to the improved cooling efficiency.

FIG.9 shows a third modification of the  
inclined columnar radiator fin. An inclined columnar  
radiator fin 70 shown in FIG.9 has a flattened  
cylindrical shape such that a cylinder is flattened  
25   more towards the tip end. The inclined columnar  
radiator fin 70 is arranged so that an approximately  
inverted triangular surface 71 faces the upstream side  
of the parallel coolant flow 43.

According to the shape of this third  
30   modification of the inclined columnar radiator fin, the  
flow resistance at the lower part of the inclined  
columnar radiator fin 70 relatively decreases with  
respect to that at the upper part of the inclined  
columnar radiator fin 70. As a result, the coolant  
35   flow in the vicinity of the top surface 11a of the  
semiconductor element 11 is stimulated, thereby  
improving the cooling efficiency.

1           FIG.10 shows a fourth modification of the  
inclined columnar radiator fin. A columnar radiator  
fin 75 shown in FIG.10 is made up of a base part 75a  
which is fixed vertically to the top surface 11a of the  
5 semiconductor element 11, and a bent part 75b which is  
bent to incline towards the upstream side of the  
parallel coolant flow 43.

          According to the shape of this fourth  
modification of the inclined columnar radiator fin, the  
10 end surface of a connecting part 76 which is provided  
at the end of the base part 75a is perpendicular to the  
direction in which the base part 75a extends. For this  
reason, it is extremely simple to align the positions  
of the connecting part 76 and the top surface 11a of  
15 the semiconductor element 11 when assembling the  
columnar radiator fin 75, and the production efficiency  
is improved.

          FIG.11 shows a fifth modification of the  
inclined columnar radiator fin. A comb shaped  
20 structure 80 shown in FIG.11 is integrally formed from  
a plurality of inclined columnar radiator fin parts 81,  
and a connecting flange 82 which connects top ends of  
the inclined columnar radiator fin parts 81.

          FIG.12A shows a plan view of the comb shaped  
25 structures 80, and FIG.12B shows a side view of the  
comb shaped structures 80. As shown in FIGS.12A and  
12B, each comb shaped structure 80 is made up of the  
inclined columnar radiator fin parts 81 which are  
integrally arranged in a direction generally  
30 perpendicular to the parallel coolant flow 43, and are  
inclined towards the upstream side of the parallel  
coolant flow 43.

          According to this fifth modification of the  
inclined columnar radiator fin, a plurality of inclined  
35 columnar radiator fin parts 81 can be assembled in  
units of the comb shaped structures 80. For this  
reason, the production process is extremely simple

1 compared to the case where the radiator fins must be  
fixed one at a time.

FIG.13 shows a sixth modification of the  
inclined columnar radiator fin. In this sixth  
5 modification, the connecting flange 82 of the comb  
shaped structure 80 shown in FIG.11 is curved towards  
the downstream side of the parallel coolant flow 43.  
In other words, a comb shaped structure 90 shown in  
FIG.13 is curved in an approximate V-shape, and is  
10 integrally formed from a plurality of inclined columnar  
radiator fins 91 and a connecting flange 92 which  
connect the top ends of the inclined columnar radiator  
fins 91.

FIG.14A shows a plan view of the comb shaped  
15 structures 90, and FIG.14B shows a side view of the  
comb shaped structures. As shown in FIGS.14A and 14B,  
each comb shaped structure 90 is curved to form an  
approximate V-shape which points towards the downstream  
side of the parallel coolant flow 43.

20 According to this sixth modification of the  
inclined columnar radiator fin, the downwardly inclined  
flow is generated in a vicinity of the inclined  
columnar radiator fin parts 91, and the curved shape of  
the comb shaped structure 90 acts so as to concentrate  
25 the parallel coolant flow 43 towards a most downstream  
side part 93 of the comb shaped structure 90. For this  
reason, it is possible to increase the amount of  
coolant passing above a region 11b of the top surface  
11a in a vicinity of the most downstream side part 93  
30 compared to that at other regions of the top surface  
11a. Therefore, it is possible to effectively cool the  
specific region 11b more efficiently, such as a part of  
the semiconductor element 11 where the generated heat  
is high.

35 Next, a description will be given of  
modifications of the arrangement of the inclined  
columnar radiator fins 37 of the first embodiment. The

1 arrangement of the inclined columnar radiator fins 37  
will hereinafter simply be referred to as the "fin  
arrangement".

FIGS.15A and 15B respectively show a plan  
5 view and a side view of a first modification of the fin  
arrangement. In FIGS.15A and 15B, the inclined  
columnar radiator fins 37 are arranged at a pitch  $P_1$  in  
an intermediate part of the semiconductor element 11  
with respect to the parallel coolant flow 43, and this  
10 pitch  $P_1$  is smaller than a pitch  $P_2$  of the inclined  
columnar radiator fins 37 arranged at other parts of  
the semiconductor element 11.

According to this first modification of the  
fin arrangement, it is possible to efficiently cool a  
15 specific part of the semiconductor element 11. Hence,  
even in a case where the semiconductor element 11 is  
formed by a package 101 which accommodates a  
semiconductor chip 100 and the heat generated from the  
central part of the package 101 is high as shown in  
20 FIG.15B, it is possible to uniformly and efficiently  
cool the semiconductor element 11.

FIG.16 shows a plan view of a second  
modification of the fin arrangement. In FIG.16, the  
inclined columnar radiator fins 37 are arranged at a  
25 pitch  $P_4$  in a downstream side part 111 of the  
semiconductor element 11 with respect to the parallel  
coolant flow 43, and this pitch  $P_4$  is smaller than a  
pitch  $P_3$  of the inclined columnar radiator fins 37  
arranged in an upstream side part 110 of the  
30 semiconductor element 11.

According to this second modification of the  
fin arrangement, the cooling efficiency of the  
semiconductor element 11 is improved at the downstream  
side part 111 compared to the upstream side part 110.  
35 On the other hand, the parallel coolant flow 43 is  
heated and the temperature thereof rises when passing  
above the semiconductor element 11, and the cooling

1 capacity of the coolant itself gradually decreases  
towards the downstream side of the parallel coolant  
flow 43. For this reason, the effects of the two  
cancel each other, so that the entire semiconductor  
5 element 11 is cooled to an approximately uniform  
temperature.

This concept of cooling can also be applied  
to a case where a plurality of semiconductor elements  
are arranged along the direction of the coolant flow.  
10 In other words, it is possible to cool each of the  
semiconductor elements to an approximately uniform  
temperature by arranging the inclined columnar radiator  
fins at a narrower pitch for those semiconductor  
elements located closer to the downstream side of the  
15 coolant flow.

Next, a description will be given of the  
modifications of the fin arrangement in which different  
kinds of inclined columnar radiator fins are arranged  
on a single semiconductor element.

20 FIG.17 shows a fin arrangement in which the  
lengths of the inclined columnar radiator fins are  
longer towards the downstream side of the parallel  
coolant flow 43. In other words, lengths  $l_{10}$ ,  $l_{11}$ ,  $l_{12}$   
and  $l_{13}$  of inclined columnar radiator fins 120, 121,  
25 122 and 123 satisfy a relation  $l_{10} < l_{11} < l_{12} < l_{13}$ .

The cooling capacity of the inclined columnar  
radiator fin becomes greater as the length of the  
inclined columnar radiator fin becomes longer. Hence,  
the fin arrangement shown in FIG.17 compensates for the  
30 decrease in the cooling capacity caused by the  
temperature rise of the parallel coolant flow 43 on the  
semiconductor element 11. As a result it is possible  
to cool the entire semiconductor element 11 to an  
approximately uniform temperature.

35 FIG.18 shows a fin arrangement in which the  
inclination angles of the inclined columnar radiator  
fins are greater towards the downstream side of the



1 parallel coolant flow 43. In other words, inclination  
angles  $\theta_{10}$ ,  $\theta_{11}$ ,  $\theta_{12}$  and  $\theta_{13}$  of inclined columnar  
radiator fins 125, 126, 127 and 128 satisfy a relation  
5  $\theta_{10} < \theta_{11} < \theta_{12} < \theta_{13}$ . In addition, the inclined columnar  
radiator fins 125 through 128 have approximately the  
same height. Consequently, the inclined columnar  
radiator fin with the greater inclination angle is also  
longer.

The cooling capacity of the inclined columnar  
10 radiator fin becomes greater as the length of the  
inclined columnar radiator fin becomes longer, and in  
addition, the effect of the means for obliquely hitting  
the coolant also becomes greater as the inclination  
15 angle of the inclined columnar radiator fin becomes  
larger. For this reason, the fin arrangement shown in  
FIG.18 compensates for the decrease in the cooling  
capacity caused by the temperature rise of the parallel  
coolant flow 43 on the semiconductor element 11. As a  
20 result it is possible to cool the entire semiconductor  
element 11 to an approximately uniform temperature.

Furthermore, since the heights of the  
inclined columnar radiator fins 125 through 128 are  
approximately the same, the parallel coolant flow 43  
hits all of the inclined columnar radiator fins 125  
25 through 128, and the cooling capacity of the coolant is  
effectively utilized.

Next, a description will be given of a second  
embodiment of the semiconductor element cooling  
apparatus according to the present invention. In this  
30 second embodiment, the means for obliquely hitting the  
coolant is formed by a fan.

FIG.19 shows the second embodiment. In  
FIG.19, those parts which are the same as those  
corresponding parts in FIG.3 are designated by the same  
35 reference numerals, and a description thereof will be  
omitted. Further, FIG.20 shows a side view for  
explaining the relationship of the fan and the

1 semiconductor element in FIG.19.

In a semiconductor element cooling apparatus 130 shown in FIGS.19 and 20, the semiconductor element 11 is mounted on the circuit substrate 12, and a heat sink 131 is provided on the semiconductor element 11.

A compact fan 133 forms an important part of this embodiment. This compact fan 133 is provided within the passage 33 and is located above the heat sink 131. In addition, the compact fan 133 is supported on the circuit substrate 12 by a support bracket 134 in an inclined position which has an inclination angle  $\alpha$  of approximately  $30^\circ$  with respect to the circuit substrate 12.

Next, a description will be given of the cooling operation of the semiconductor element cooling apparatus 130.

The fan 35 and the compact fan 133 are driven. When the fan 35 is driven, the air is drawn in as the coolant via the coolant inlet 36, and the parallel coolant flow 43 which is parallel to the circuit substrate 12 is formed within the passage 33. On the other hand, when the compact fan 133 is driven, a-parallel coolant flow portion 43-1 which is close to the passage forming member 32 out of the parallel coolant flow 43 is drawn in by the compact fan 133 and is ejected in the form of an ejected coolant flow portion 135 as indicated by an arrow. This ejected coolant flow portion 135 forms an angle  $\alpha$  towards the downstream side of the parallel coolant flow 43 with respect to a line 138 which is perpendicular to the circuit substrate 12.

On the other hand, out of the parallel coolant flow 43, a parallel coolant flow portion 43-2 which is close to the circuit substrate 12 hits the heat sink 131. In addition, the above ejected coolant flow portion 135 also hits the heat sink 131. Hence, the heat of the heat sink 131 is absorbed by both the

1 parallel coolant flow portion 43-2 and the ejected  
coolant flow portion 135, and the semiconductor element  
11 is efficiently cooled.

5 Next, a description will be given of the  
advantages of providing the compact fan 131 in the  
inclined position.

First, it is possible to efficiently secure a  
draw-in area 136. Since the space between the passage  
forming member 32 and the compact fan 133 within the  
10 draw-in area 136 spreads towards the upstream side of  
the parallel coolant flow 43, it becomes easier to draw  
in the parallel coolant flow 43.

Second, the ejected coolant flow portion 135  
is inclined towards the downstream side of the parallel  
15 coolant flow 43. For this reason, the ejected coolant  
flow portion 135 after hitting the heat sink 131 more  
easily flows to the downstream side of the parallel  
coolant flow 43 as indicated by an arrow 137, and is  
unlikely to interfere with the flow of the parallel  
20 coolant flow 43.

Third, the ejected coolant flow portion 135  
after hitting the heat sink 131, indicated by the arrow  
137, acts to increase the flow velocity of the parallel  
coolant flow 43. As the flow velocity of the parallel  
25 coolant flow 43 increases, the cooling efficiency  
improves.

Next, a description will be given of  
modifications of the second embodiment described above.

FIG.21 shows a first modification of the  
30 second embodiment.

In FIG.21, a guide plate 140 is provided on  
the downstream side of the compact fan 133. Out of the  
ejected coolant flow portion 135 from the compact fan  
133, the guide plate 140 forcibly guides an ejected  
35 coolant flow portion 135-1 which is pushed towards the  
downstream side of the parallel coolant flow 43 and  
would otherwise not reach the heat sink 131, as

1 indicated by an arrow 135-2, so as to reach the heat  
sink 131. This first modification is particularly  
effective when the height of the passage of the  
parallel coolant flow 43 is restricted and the compact  
5 fan 133 must be inclined by a large angle.

According to this first modification, it is  
possible to efficiently cool the semiconductor element  
11.

FIG.22 shows a second modification of the  
10 second embodiment.

In FIG.22, a guide duct 150 is provided in  
place of the guide plate 140 shown in FIG.21. Compared  
to the guide plate 140 of the first modification, the  
provision of the guide duct 150 increases the amount of  
15 coolant flow hitting the heat sink 131, thereby further  
improving the cooling efficiency.

FIG.23 shows a third modification of the  
second embodiment.

In FIG.23, a guide member 160 made up of wall  
20 portions 160a, 160b and 160c and having an approximate  
U-shape is additionally provided in the semiconductor  
element cooling apparatus 130 shown in FIGS.19 and 20.  
This guide member 160 is provide on the circuit  
substrate 12 so as to generally surround the  
25 semiconductor element 11.

By the provision of the guide member 160, the  
coolant flow which is directed towards the heat sink  
131 by the compact fan 133 is restricted from spreading  
to the right and left and to the upstream direction  
30 when viewed in the flow direction of the parallel  
coolant flow 43, as indicated by arrows 161, 162 and  
163. As a result, the coolant flows only in the  
downstream direction of the parallel coolant flow 43 as  
indicated by an arrow 164.

35 According to this third modification, it is  
possible to prevent undesirable effects to other  
circuit elements on the periphery of the semiconductor

1 element 11.

FIG.24 shows a fourth modification of the second embodiment.

5 In FIG.24, a guide member 160A has a flange portion 160d along the upper end of the guide member 160 shown in FIG.23. In other words, the flange portion 160d extends along the upper end of the guide member 160A and projects to the inside.

10 By the provision of the flange portion 160d, even if coolant flows 161a, 162a and 163a are generated and move upwardly along the respective wall portions 160a, 160b and 160c, the coolant flows 161a, 162a and 163a hit the flange portion 160d and is prevented from escaping upwardly of the guide member 160A.

15 Therefore, the coolant which has absorbed heat and flows upwardly will not move around to the draw-in side of the compact fan 133 and raise the temperature of the ejected coolant flow portion 135. Hence, this fourth modification can prevent the cooling  
20 effect from deteriorating due to the coolant which may otherwise reach the draw-in side of the compact fan 133 if the flange portion 160d is not provided.

FIG.25 shows a fifth modification of the second embodiment.

25 In FIG.25, the compact fan 133 is supported on the circuit substrate 12 by the support bracket 134. In addition, a partition member 170 is provided between the support bracket 134 and the passage forming member 32. The partition member 170 is made up of left and  
30 right sidewalls 170a and 170b, and a wall 170c on the downstream side of the compact fan 133. The partition member 170 has an approximate U-shape and surrounds the compact fan 133 except for the draw-in area 136.

35 The partition member 170 partitions the draw-in side and the ejection side of the compact fan 133, so as to prevent the ejected coolant flow portion 135 from moving around to the draw-in side. In addition,

1 the provision of the partition member 170 enables  
mounting of a stable fan which is strong against  
vibration and shock.

5 Similarly to the fourth modification, this  
fifth modification provides an effective means of  
preventing the heated coolant from moving around to the  
draw-in side of the compact fan 133 when the ejected  
coolant flow portion 135 from the compact fan 133 is  
strong relative to the parallel coolant flow 43.

10 FIGS.26 and 27 show a sixth modification of  
the second embodiment.

In FIGS.26 and 27, a duct forming member 180  
is provided at a position in a vicinity of the passage  
forming member 32 within the passage 33. The duct  
15 forming member 180 and the passage forming member 32  
form a duct 181.

An opening 181a at one end of the duct 181  
opens to the draw-in area 136 of the compact fan 133.  
The other open end (not shown) of the duct 181 opens  
20 for example to the coolant inlet 36 of the passage 33  
shown in FIG.19. A parallel coolant flow is also  
generated within the duct 181 by the fan 35 shown in  
FIG.19, similarly to the inside of the passage 33. The  
parallel coolant flow within the duct 181 is indicated  
25 by a reference numeral 43A, and the parallel coolant  
flow outside the duct 181 is indicated by a reference  
numeral 43B.

Next, a description will be given of the duct  
181.

30 The compact fan 133 draws in and ejects only  
the parallel coolant flow 43A which is received via the  
duct 181.

On the other hand, the duct 181 prevents the  
draw-in force of the compact fan 133 from affecting the  
35 parallel coolant flow 43B. A semiconductor element 182  
shown in FIG.27 is located at a position immediately in  
front of the semiconductor element 11 in the flow

1 direction of the parallel coolant flow 43. Hence, the  
compact fan 133 will not draw in the parallel coolant  
flow 43B for cooling the semiconductor element 182 and  
give undesirable effects on the air surrounding the  
5 semiconductor element 182. In addition, it is also  
possible to prevent a parallel coolant flow 43Ba which  
passes the semiconductor element 182 and is heated  
thereby from being drawn in by the compact fan 133, and  
thus, the temperature of the air ejected from the  
10 compact fan 133 will not be increased by the parallel  
coolant flow 43Ba.

Therefore, this sixth modification can not  
only efficiently cool the semiconductor element 11, but  
also cool the semiconductor element 182 without being  
15 affected by the cooling of the semiconductor element  
11.

Next, a description will be given of a third  
embodiment of the semiconductor element cooling  
apparatus according to the present invention.

20 FIG.28 shows the third embodiment. In a  
semiconductor element cooling apparatus 190 shown in  
FIG.28, a duct forms the means for obliquely hitting  
the coolant.

In FIG.28, the semiconductor element 11 is  
25 mounted on the circuit substrate 12, and the heat sink  
131 is provided on this semiconductor element 11. A  
duct 191 has an outlet 192 which is arranged obliquely  
to the semiconductor element 11. A compact fan 194 is  
mounted at an inlet 193 of this duct 191.

30 The parallel coolant flow 43 and an ejected  
coolant flow 195 which is ejected obliquely from the  
outlet 192 of the duct 191 hit the semiconductor  
element 11. Hence, the semiconductor element 11 is  
efficiently cooled for reasons similar to the case  
35 where the compact fan 133 is obliquely arranged as  
described above.

Next, a description will be given of a fourth

1     embodiment of the semiconductor element cooling  
apparatus according to the present invention.

FIGS.29 and 30 show the fourth embodiment.  
In a semiconductor cooling apparatus 200 shown in  
5     FIGS.29 and 30, inclined columnar radiator fins which  
are inclined towards the upstream side of the coolant  
flow form the means for obliquely hitting the coolant,  
similarly to the first embodiment. However, this  
fourth embodiment obtains the coolant flow by a coolant  
10    ejected from the nozzle.

In FIGS.29 and 30, a plurality of inclined  
columnar radiator fins 201 are arranged on the top  
surface 11a of the semiconductor element 11,  
concentrically about a center of the semiconductor  
15    element 11. In addition, the inclined columnar  
radiator fins 201 are inclined at an angle  $\theta$  towards  
the center of the semiconductor element 11. The nozzle  
21 is provided above the semiconductor element 11 so as  
to confront the top surface 11a of the semiconductor  
20    element 11.

The high-speed coolant flow 22 ejected from  
the nozzle 21 at a high speed hits the center of the  
top surface 11a of the semiconductor element 11, and  
thereafter forms the jet flow 23 which spreads radially  
25    along the top surface 11a. This radial jet flow 23  
absorbs the heat from the top surface 11a and the  
inclined columnar radiator fins 201, and cools the  
semiconductor element 11.

Each of the inclined columnar radiator fins  
30    201 are inclined towards the upstream side of the  
radial jet flow 23. For this reason, a downward flow  
202 is generated similarly to the first embodiment, and  
stimulates the coolant flow at the top surface 11a of  
the semiconductor element 11. In addition, the surface  
35    area of the inclined columnar radiator fin 202 is  
increased. As a result, it is possible to improve the  
cooling efficiency with respect to the semiconductor



1 element 11.

Next, a description will be given of a fifth embodiment of the semiconductor element cooling apparatus according to the present invention.

5 FIGS.31 through 35 show the fifth embodiment. FIG.31 is a perspective view, with a part cut away, showing the fifth embodiment. FIG.32 is a plan view showing an important part of the fifth embodiment shown in FIG.31. FIG.33 is a front view showing an important  
10 part of the fifth embodiment shown in FIG.31. FIG.34 is a diagram showing the fifth embodiment shown in FIG.31 viewed from the direction of the flow of the coolant. Further, FIG.35 is a side view for explaining the operation of the fifth embodiment shown in FIG.31.  
15 In FIGS.31 through 35, those parts which are the same as those corresponding parts in FIG.3 are designated by the same reference numerals, and a description thereof will be omitted.

In FIGS.31 through 35, a partition member 211  
20 is provided on the passage forming member 32 confronting the top surface 11a of the semiconductor element 11, for a length corresponding to approximately the full width of the flow in a direction generally perpendicular to the parallel coolant flow 43. The  
25 partition member 211 confronts a part of the top surface 11a on the upstream side of the semiconductor element 11. A narrow gap is formed between the partition member 211 and the top surface 11a of the semiconductor element 11, and functions as a slit-  
30 shaped coolant outlet 212.

During operation of the electronic equipment, the fan 35 which is used as the coolant driving unit is driven. As a result, the air is drawn in as the  
coolant from the coolant inlet 36, and the parallel  
35 coolant flow 43 is generated within the passage 33. FIG.35 shows the flow in the vicinity of the semiconductor element 11 caused by the parallel coolant

1 flow 43. In FIG.35, the arrows generally show the  
velocity distribution of the coolant flow within the  
passage 33.

The flow quantity of the parallel coolant  
5 flow 43 is constant at an arbitrary cross section of  
the passage 33. Hence, the coolant flow is accelerated  
when entering within the gap between the top surface  
11a of the semiconductor element 11 and the partition  
member 211 which narrows the cross section of the  
10 passage 33, and an extremely high-speed flow 213 is  
generated. This high-speed flow 213 is ejected at the  
high speed from the slit-shaped coolant outlet 212 for  
the entire width thereof, and forms a two-dimensional  
jet flow 214 on the top surface 11a of the  
15 semiconductor element 11 on the downstream side of the  
partition member 211.

As a result, the high-speed flow 213 in  
contact with the top surface 11a of the semiconductor  
element 11 efficiently absorbs the heat from the  
20 semiconductor element 11. In addition, extremely  
complex flows accompanying air eddy of various sizes  
are generated in the region of the two-dimensional jet  
flow 214, and the coolant is violently mixed, thereby  
stimulating the convection heat transfer within the  
25 coolant. Because of these effects, the cooling  
efficiency of the semiconductor element 11 is further  
improved.

Furthermore, although utilizing the high  
cooling efficiency of such a jet flow, this embodiment  
30 does not require a nozzle structure as in the  
conceivable case. For this reason, it is possible to  
mount a plurality of circuit substrates 12 or  
semiconductor elements 11 at a narrow pitch within the  
electronic equipment, that is, with a high mounting  
35 density, and cool the semiconductor elements 11  
similarly to the normal cooling using the parallel  
coolant flow 43.

1           The effect of improving the cooling  
efficiency becomes greater as the flow velocity of the  
high-speed flow 213 becomes faster. The flow velocity  
v can be adjusted by the height b of the slit-shaped  
5 coolant outlet 212. In other words, the following  
formula (1) stands between the flow velocity v and the  
height b, where h denotes the gap between the top  
surface 11a of the semiconductor element 11 and the  
surface of the passage forming member 32, t denotes the  
10 height of the semiconductor element 11 in the mounted  
state, and  $v_0$  denotes an average flow velocity of the  
parallel coolant flow 43 at a position in front of the  
semiconductor element 11.

$$v = [h+t]/b \cdot v_0 \quad \text{--- (1)}$$

15           However, when the flow velocity is increased,  
the pressure loss of the coolant also increases at the  
downstream side of the semiconductor element 11 when  
compared to that at the upstream side of the  
semiconductor element 11, and the load on the coolant  
20 driving unit 35 accordingly increases. Hence, from the  
practical point of view, it is necessary to  
appropriately set the value of the height b within a  
range such that a sufficiently large flow velocity v  
that would develop disturbed flow having air eddy of  
25 various sizes can be obtained in the region of the two-  
dimensional jet flow 214.

In addition, similarly as in the case of the  
first embodiment, the kind of semiconductor element 11,  
the kind of coolant used, the method of forming each  
30 surface of the passage forming member 32 may be  
selected arbitrarily, so that the above described  
effects are obtainable.

Next, a description will be given of  
modifications of the fifth embodiment.

35           FIG.36 shows a first modification of the  
fifth embodiment. A partition member 220 shown in  
FIG.36 has an inclined surface 221 on the upstream side

1       thereof. When viewed from the passage forming member  
32, the surface 221 is inclined towards the downstream  
side of the parallel coolant flow 34. In this  
modification, the entire surface 221 is inclined.

5               According to this first modification, the  
parallel coolant flow 43 is guided by the inclined  
surface 221 as indicated by an arrow 222 and is  
smoothly guided towards the slit-shaped coolant outlet  
212. For this reason, the coolant flow in the vicinity  
10 of the upstream side of the partition member 220 is  
smooth, and it is possible to reduce the pressure loss.

FIGS.37 and 38 show an application of this  
first modification to a circuit substrate module 230.  
FIG.37 shows a cross section of the circuit substrate  
15 module 230, and FIG.38 shows a cross section taken  
along a line XXXVI-XXXVI in FIG.37.

In FIGS.37 and 38, a plurality of circuit  
substrates 12-1, 12-2 and 12-3 are accommodated within  
a sealed container 231. The circuit boards 12-1, 12-2  
20 and 12-3 are coupled to a mother board 234 via a  
connector 233 as shown in FIG.38. A plurality of  
semiconductor elements 11 are mounted on each of the  
circuit substrates 12-1, 12-2 and 12-3 in a matrix  
arrangement. Each partition member 220 is mounted on  
25 the adjacent circuit substrate so as to confront the  
semiconductor elements 11 on the circuit substrates 12-  
1, 12-2 and 12-3. With respect to the uppermost  
circuit substrate 12-1, the partition member 220 is  
mounted on the inner wall of the sealed container 231.

30               Before passing inside the sealed container  
231 and reaching an outlet 236, a coolant 235 hits the  
partition members 220 and forms the two-dimensional jet  
flow on the downstream side of each partition member  
220. Hence, the semiconductor elements 11 are  
35 efficiently cooled. In other words, this first  
modification can utilize the high cooling efficiency of  
the jet flow and also increase to the limit the

1 mounting density of the semiconductor elements 11  
within the electronic equipment.

FIG.39 shows a second modification of the  
fifth embodiment.

5 As shown in FIG.39, a plurality of partition  
members 240-1, 240-2 and 240-3 are provided with  
respect to one semiconductor element 11. The partition  
members 240-1, 240-2 and 240-3 are arranged in the  
10 direction of the parallel coolant flow 43 at arbitrary  
intervals. Slit-shaped coolant outlets 241-1, 241-2  
and 241-3 are formed between the semiconductor element  
11 and the corresponding partition members 240-1, 240-2  
and 240-3, and two-dimensional jet flows 242-1, 242-2  
and 242-3 are formed on the downstream sides of the  
15 corresponding slit-shaped coolant outlets 241-1, 241-2  
and 241-3. For this reason, the entire surface of the  
semiconductor element 11 is uniformly cooled with a  
satisfactory efficiency.

FIG.40 shows an electronic equipment 250  
20 which is applied with the second modification shown in  
FIG.39. In FIG.40, the semiconductor element 11 which  
generates heat with a relatively high density and other  
semiconductor elements 253 which generate heat with a  
relatively low density coexist on the circuit substrate  
25 12.

A passage forming member 255 is directly  
mounted on the semiconductor element 11 so as to cover  
the top surface 11a thereof, and a passage 256 is  
formed between the passage forming member 255 and the  
30 top surface 11a. The partition members 240-1, 240-2  
and 240-3 similar to those shown in FIG.39 are provided  
on the surface of the passage forming member 255 on the  
side of the passage 256. The coolant is supplied to  
the passage 256 via a joint 259 and a pipe 257; and the  
35 two-dimensional jet flows 242-1, 242-2 and 242-3 are  
generated so as to cool the semiconductor element 11.

When using compressed air as the coolant, the

1 air ejected from the passage 256 is released to the  
atmosphere via a muffler 258 if necessary.

On the other hand, the other semiconductor  
elements 253 are cooled by a parallel air flow 254  
5 generated within a passage 252 by a fan 251.

Hence, according to this second modification,  
it is possible to cool a small number of semiconductor  
elements 11 which generate heat with a relatively large  
density together with other semiconductor elements 253  
10 which generate heat with a relatively small density and  
coexist on the circuit substrate 12 within the  
electronic equipment. For this reason, it is possible  
to improve the mounting density of the semiconductor  
elements. In addition, since the positional  
15 relationship of the semiconductor elements and the  
passage forming member 255 and the partition members  
240-1, 240-2 and 240-3 can be fixed without via the  
circuit substrate 12, the assembling process becomes  
simple and the cooling performance stabilizes.

20 FIG.41 shows a third modification of the  
fifth embodiment.

In FIG.41, a plurality of partition members  
260-1, 260-2 and 260-3 are arranged at arbitrary  
intervals along the direction of the parallel coolant  
25 flow 43 with respect to one semiconductor element 11.  
In addition, the lengths of the partition members 260-  
1, 260-2 and 260-3 in a direction perpendicular to the  
parallel coolant flow 43 are longer for the partition  
members located closer to the downstream side of the  
30 parallel coolant flow 43. In other words, slit-shaped  
coolant outlets 261-1, 261-2 and 261-3 are formed  
between the top surface 11a of the semiconductor  
element 11 and the corresponding partition members 260-  
1, 260-2 and 260-3, and gaps  $b_1$ ,  $b_2$  and  $b_3$  of the slit-  
35 shaped coolant outlets 261-1, 261-2 and 261-3 satisfy a  
relation  $b_1 > b_2 > b_3$ .

The flow quantity of the parallel coolant

1 flow 43 is constant at various parts along the  
semiconductor element 11. Hence, by employing the  
above described construction, it is possible to  
generate a two-dimensional jet flow which is faster at  
5 the slit-shaped coolant outlet located closer to the  
downstream side of the parallel coolant flow 43. For  
this reason, the cooling capacity improves towards the  
downstream side of the parallel coolant flow 43, and it  
is possible to compensate for the deterioration of the  
10 cooling capacity caused by the temperature rise of the  
parallel coolant flow 43 above the semiconductor  
element 11. Accordingly, it is possible to cool the  
entire semiconductor element 11 to an approximately  
uniform temperature.

15 FIG.42 shows a fourth modification of the  
fifth embodiment. In this fourth modification, the  
concept of the third modification shown in FIG.41 is  
applied to a plurality of semiconductor elements 11-1  
and 11-2 which are arranged along the parallel coolant  
20 flow 43.

In FIG.42, partition members 270-1 and 270-2  
are provided to confront the corresponding  
semiconductor elements 11-1 and 11-2. Slit-shaped  
coolant outlets 271-1 and 271-2 are respectively formed  
25 between the semiconductor elements 11-1 and 11-2 and  
the partition members 270-1 and 270-2. Gaps  $b_{11}$  and  
 $b_{12}$  of the slit-shaped coolant outlets 271-1 and 271-2  
satisfy a relation  $b_{11} > b_{12}$ . In other words, the gap  
becomes narrower towards the downstream side of the  
30 parallel coolant flow 43.

By employing the above described  
construction, the two-dimensional jet flow generated is  
faster at the slit-shaped coolant outlet located closer  
to the downstream side of the parallel coolant flow 43,  
35 similarly as in the case of the third modification of  
the fifth embodiment. For this reason, the cooling  
capacity improves towards the downstream side of the

1 parallel coolant flow 43, and it is possible to  
compensate for the deterioration of the cooling  
capacity caused by the temperature rise of the parallel  
coolant flow 43 above the semiconductor elements 11-1  
5 and 11-2. Accordingly, it is possible to cool the  
semiconductor elements 11-1 and 11-2 in their entirety  
to an approximately uniform temperature.

FIG.43 shows a fifth modification of the  
fifth embodiment. In this fifth modification, the  
10 semiconductor element 11 includes a plurality of built-  
in semiconductor chips 282-1, 282-2 and 282-3, and the  
heat generated from the semiconductor element 11 is  
different depending on the parts of the semiconductor  
element 11. For the sake of convenience, it is assumed  
15 that the heat generated is the highest at the central  
part of the semiconductor element 11.

In FIG.43, a plurality of partition members  
283-1, 283-2 and 283-3 are arranged at arbitrary  
intervals along the direction of the parallel coolant  
20 flow 43. Slit-shaped coolant outlets 284-1, 284-2 and  
284-3 are formed between the top surface 11a of the  
semiconductor element 11 and the corresponding  
partition members 283-1, 283-2 and 283-3. Gaps  $b_{21}$ ,  
 $b_{22}$  and  $b_{23}$  of the slit-shaped coolant outlets 284-1,  
25 284-2 and 284-3 satisfy relations  $b_{21} > b_{22}$  and  $b_{23} > b_{22}$ ,  
so that the gap becomes narrower towards the part of  
the semiconductor element 11 generating higher heat.

The flow quantity of the parallel coolant  
flow 43 is constant at various parts along the  
30 semiconductor element 11. For this reason, by  
employing the above described construction, the two-  
dimensional jet flow generated is faster at the slit-  
shaped coolant outlet provided at the part of the  
semiconductor element 11 generating high heat. As a  
35 result, the cooling capacity is improved for the part  
of the semiconductor element 11 generating the high  
heat, and it is possible to cool the entire



1 semiconductor element 11 to an approximately uniform  
temperature.

FIG.44 shows a sixth modification of the  
fifth embodiment. In this sixth modification, a  
5 partition member 290 confronts the top surface 11a of  
the semiconductor element 11, and a plurality of  
undulations (or zigzag patterns) 291 are formed on the  
end of the partition member 290 when viewed from the  
downstream side of the parallel coolant flow 43.

10 In FIG.44, the gap of a slit-shaped coolant  
outlet 292 differs between the mountain portion and the  
valley portion of the undulations 291. The resistance  
to the coolant is smaller at the larger gap when  
ejecting the coolant from the slit-shaped coolant  
15 outlet 292, and the coolant more easily flows through  
the larger gap. Hence, the coolant flow ejected from  
the slit-shaped coolant outlet 292 has a distribution  
such that the flow quantity alternately increases and  
decreases along the longitudinal direction of the slit-  
20 shaped coolant outlet 292. Consequently, the  
convection of the coolant along a width W of the  
semiconductor element 11 is stimulated, and the cooling  
efficiency with respect to the semiconductor element 11  
is improved.

25 FIG.45 shows a seventh modification of the  
fifth embodiment. In this seventh modification, a  
partition member 300 confronts the top surface 11a of  
the semiconductor element 11. A semi-circular groove  
301 is formed at the end of the partition member 300  
30 when viewed from the downstream side of the parallel  
coolant flow 43.

In FIG.45, the gap of a slit-shaped coolant  
outlet 302 becomes larger at the groove 301. Hence,  
the flow quantity of the coolant ejected from the slit-  
35 shaped coolant outlet 302 is increased at the groove  
301. As a result, it is possible to more efficiently  
cool a part 11c of the semiconductor element 11

1 corresponding to the groove 301.

FIG.46 shows an eighth modification of the fifth embodiment.

5 In FIG.46, a V-shaped groove 311 traverses approximately a center of the top surface 11a of the semiconductor element 11. A partition member 314 is inclined to the downstream side of the parallel coolant flow 43, and a tip part 314a of the partition member 314 enters within the V-shaped groove 311 and confronts  
10 a surface 312 on the upstream side of the V-shaped groove 311. A slit-shaped coolant outlet 315 is formed between the tip part 314a and the surface 312.

A two-dimensional jet flow 316 ejected from the slit-shaped coolant outlet 315 first flows along  
15 the surface 312 on the upstream side of the V-shaped groove 311, then hits a surface 313 on the downstream side of the V-shaped groove 311 and rapidly changes direction, and thereafter flows along the surface 313 towards the downstream side as indicated by an arrow  
20 317 in FIG.46. The rapid change in the flow direction caused by such a collision at the surface 313 acts to further and more violently mix the coolant flow. As a result, it is possible to obtain a higher cooling efficiency with respect to the semiconductor element  
25 11.

FIG.47 shows a ninth modification of the fifth embodiment.

In FIG.47, a partition member 320 which is provided on the passage forming member 32 has an L-  
30 shaped cross section when viewed from the side. A slit-shaped coolant outlet 321 is formed between the partition member 320 and the top surface 11a of the semiconductor element 11. On the other hand, a fin 322 having a rectangular cross section is provided on the  
35 top surface 11a of the semiconductor element 11 on the downstream side of the slit-shaped coolant outlet 321. This fin 322 is provided in parallel to the slit-shaped

1 coolant outlet 321 with a predetermined interval formed  
therebetween.

5 A two-dimensional jet flow 323 ejected from  
the slit-shaped coolant outlet 321 hits a vertical  
surface 324 on the upstream side of the fin 322 and  
changes direction as indicated by an arrow 325. For  
this reason, it is possible to improve the cooling  
efficiency with respect to the semiconductor element  
11, similarly to the eighth modification of the fifth  
10 embodiment. Furthermore, this ninth modification can  
be applied to a case where it is difficult to form a  
groove on the semiconductor element itself, such as the  
case of a bear chip.

15 FIGS.48A and 48B show a tenth modification of  
the fifth embodiment. FIG.48A shows a side view of the  
tenth modification, and FIG.48B shows a plan view of  
the semiconductor element of the tenth modification.  
According to this tenth modification, the fin of the  
ninth modification of the fifth embodiment shown in  
20 FIG.47 is divided into a plurality of fin pieces along  
the longitudinal direction thereof.

A plurality of partition members 330-1, 330-2  
and 330-3 are arranged at arbitrary intervals on the  
passage forming member 32 as shown in FIG.48A, and fins  
25 331 and 332 are provided in correspondence with the two  
partition members 330-1 and 330-2 on the upstream side  
of the parallel coolant flow 43. The fin 331 is made  
up of a plurality of fin pieces 331-1 through 331-4,  
and the fin 332 is made up of a plurality of fin pieces  
30 332-1 through 332-4.

By employing this construction, it is  
possible to shorten a length L of each fin piece, and  
accordingly suppress the thermal stress which is  
generated due to a difference in the thermal expansions  
35 of the semiconductor element 11 and the fins 331 and  
332. In addition, a side surface 333 is formed on each  
fin piece and the surface area of the fins 331 and 332

1 as a whole is increased, thereby improving the cooling efficiency.

FIG.49 shows an eleventh modification of the fifth embodiment.

5 In FIG.49, a plurality of fins 340-1, 340-2 and 340-3 having a rectangular cross section are provided on the top surface 11a of the semiconductor element 11. In addition, a plurality of partition members 341-1, 341-2 and 341-3 are arranged at  
10 arbitrary intervals on the passage forming member 32. The partition members 341-1, 341-2 and 341-3 respectively confront vertical surfaces 340-1a, 340-2a and 340-3a on the downstream sides of the fins 340-1, 340-2 and 340-3 with a predetermined gap formed  
15 therebetween, so as to form slit-shaped coolant outlets 342-1, 342-2 and 342-3.

By employing this construction, two-dimensional jet flows 343-1, 343-2 and 343-3 ejected from the slit-shaped coolant outlets 342-1, 342-2 and  
20 342-3 hit the top surface 11a of the semiconductor element 11 and the heat transfer distance is shortened. As a result, it is possible to effectively utilize the high cooling efficiency at the parts where the coolant hits the top surface 11a.

25 FIG.50 shows a twelfth modification of the fifth embodiment.

In FIG.50, a partition member 350 confronts a vertical surface 351a on the downstream side of a fin 351 which is provided on the top surface 11a of the  
30 semiconductor element 11. A predetermined gap is formed between the partition member 350 and the vertical surface 351a, to form a slit-shaped coolant outlet 352. In addition, a cutout groove 351b is provided on the lower end of the vertical surface 351a  
35 and extends in the longitudinal direction of the fin 351. This cutout groove 351a spreads a region 354 where a jet flow 353 from the slit-shaped coolant

1 outlet 352 hits the top surface 11a of the  
semiconductor element 11, in a direction towards the  
upstream side of the parallel coolant flow 43.

5 By employing this construction, the jet flow  
353 becomes the two-dimensional jet flow and collides  
in the large region 354. In addition, the surface area  
of the fin 351 is large. As a result, the cooling  
efficiency with respect to the semiconductor element 11  
is improved.

10 FIGS.51A and 51B show a thirteenth  
modification of the fifth embodiment. FIG.51A shows a  
plan view of the thirteenth modification, and FIG.51B  
shows a perspective view of the thirteenth  
modification.

15 A plurality of spacer members 350 and 361 are  
provided on the top surface 11a of the semiconductor  
element 11 along the direction of the parallel coolant  
flow 43, as shown in FIG.51B. In addition, as shown in  
FIG.51A, a resilient partition member 362 is provided  
20 on the passage forming member 32. This resilient  
partition member 362 is made of a resilient plate. The  
resilient partition member 362 confronts the  
semiconductor element 11 in a state where tip ends of  
the resilient partition member 362 pushes against the  
25 spacer members 360 and 361.

A slit-shaped coolant outlet 363 having a gap  
of a high accuracy corresponding to the thickness of  
the spacer members 360 and 361 is automatically formed  
between the resilient partition member 362 and the top  
30 surface 11a of the semiconductor element 11 by the  
resilient deformation of the resilient partition member  
362. For this reason, it is possible to absorb an  
error in the positional relationship between the  
passage forming member 32 and the semiconductor element  
35 11, and the assembling process is facilitated and the  
cooling performance stabilizes.

Various resilient materials may be used for

1 the resilient partition member 362. Examples of such  
resilient materials are various kinds of resins, and  
alloys such as phosphor bronze and beryllium copper.

5 FIGS. 52A, 52B and 52C show a fourteenth  
modification of the fifth embodiment. FIG. 52A shows a  
side view of the fourteenth modification, and FIGS. 52B  
and 52C show perspective views of the fourteenth  
modification. According to this fourteenth  
10 modification, the resilient partition member has the  
function corresponding to the spacer members of the  
thirteenth modification of the fifth embodiment shown  
in FIGS. 51A and 51B.

As shown in FIGS. 52A and 52B, a resilient  
partition member 370 is provided with a plurality of  
15 spacer members 371 at a tip end confronting the top  
surface 11a of the semiconductor element 11. The  
resilient partition member 370 is made of a resilient  
plate.

Alternatively, as shown in FIGS. 52A and 52C,  
20 a resilient partition member 372 is provided with a  
plurality of cutout parts 372a at a tip end confronting  
the top surface 11a of the semiconductor element 11.  
The resilient partition member 372 is made of a  
resilient plate. In addition, the cutout parts 372a  
25 are bent towards the semiconductor element 11.

In other words, the spacer members 371 at the  
tip end of the resilient partition member 370 and the  
cutout parts 372a at the tip end of the resilient  
partition member 372 push against the top surface 11a  
30 of the semiconductor element 11 and confront the  
semiconductor element 11. Therefore, by employing the  
above described construction, it is possible to easily  
form a slit-shaped coolant outlet 393 having a gap with  
a high accuracy, similarly to the thirteenth  
35 modification of the fifth embodiment.

Further, the present invention is not limited  
to these embodiments, but various variations and

1     modifications may be made without departing from the  
scope of the present invention.

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WHAT IS CLAIMED IS

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1. A semiconductor element cooling apparatus adapted to cool at least one semiconductor element mounted on a circuit substrate, said semiconductor element cooling apparatus comprising:

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first means for generating a coolant flow by flowing a coolant over a top surface of the semiconductor element; and

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second means for obliquely hitting the coolant on the semiconductor element from an upstream side towards a downstream side of the coolant flow.

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2. The semiconductor element cooling apparatus as claimed in claim 1, wherein said second means comprises:

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a plurality of inclined pillar-shaped radiator fins provided on the top surface of the semiconductor element and respectively having a portion which is inclined to the upstream side of the coolant flow.

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3. The semiconductor element cooling apparatus as claimed in claim 2, wherein said second means further comprises:

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a comb shaped structure connecting top ends of the inclined pillar-shaped radiator fins which are arranged in a direction generally perpendicular to a direction of the coolant flow.



1                   4. The semiconductor element cooling  
apparatus as claimed in claim 1, wherein said first  
means comprises:

5                   a passage forming member forming a passage between  
said passage forming member and the top surface of the  
semiconductor element; and

10                  a coolant driving unit for supplying the coolant  
to the passage so as to form a parallel coolant flow  
within the passage, said parallel coolant flow being  
approximately parallel to the top surface of the  
semiconductor element,  
and said second means comprises:

15                  a fan which is provided at a position confronting  
the semiconductor element and is inclined with respect  
to the top surface of the semiconductor element.

20                   5. The semiconductor element cooling  
apparatus as claimed in claim 4, which further  
comprises:

25                  third means, provided on a periphery of said fan,  
for restricting the coolant ejected from said fan from  
moving around to a draw-in side of said fan.

30                   6. The semiconductor element cooling  
apparatus as claimed in claim 1, wherein said first  
means comprises:

35                  a passage forming member forming a passage between  
said passage forming member and the top surface of the  
semiconductor element; and

                  a coolant driving unit for supplying the coolant  
to the passage so as to form a parallel coolant flow

1     ~~within the passage~~, said parallel coolant flow being  
approximately parallel to the top surface of the  
semiconductor element,  
and said second means comprises:

5             a duct having a tip end which confronts the  
semiconductor element and is inclined with respect to  
the top surface of the semiconductor element; and  
a fan ejecting the coolant from said duct.

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7. A semiconductor element cooling apparatus  
adapted to cool at least one semiconductor element  
15     mounted on a circuit substrate, said semiconductor  
element cooling apparatus comprising:

a passage forming member forming a passage between  
said passage forming member and a top surface of the  
semiconductor element;

20             a coolant driving unit supplying a coolant to the  
passage so as to form a parallel coolant flow above the  
top surface of the semiconductor element, said parallel  
coolant flow being approximately parallel to the top  
surface of the semiconductor element; and

25             one or a plurality of partition members provided  
on a surface of said passage forming member confronting  
the top surface of the semiconductor element,

each of said partition members having a base part  
which extends in a direction generally perpendicular to  
30     the parallel coolant flow, and a tip part which forms a  
slit-shaped coolant outlet having a predetermined gap  
between the tip part and the top surface of the  
semiconductor element.

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1           8. The semiconductor element cooling  
apparatus as claimed in claim 7, wherein said plurality  
of partition members are arranged in a direction of the  
parallel coolant flow.

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9. The semiconductor element cooling  
10 apparatus as claimed in claim 7, which further  
comprises:

one or a plurality of surfaces provided on the top  
surface of the semiconductor element,  
the coolant ejected from said slit-shaped coolant  
15 outlet hitting said one or plurality of surfaces.

20           10. The semiconductor element cooling  
apparatus as claimed in claim 9, wherein said one or a  
plurality of surfaces is perpendicular to or is  
inclined with respect to a direction in which the  
coolant is ejected from said slit-shaped coolant  
25 outlet.

30           11. The semiconductor element cooling  
apparatus as claimed in claim 10, wherein said slit-  
shaped coolant outlet and a corresponding one of said  
plurality of surfaces are arranged parallel to each  
other with a predetermined interval therebetween along  
35 a direction of the parallel coolant flow.

1           12. The semiconductor element cooling  
apparatus as claimed in claim 7, wherein said one or  
plurality of partition members structurally connect to  
the semiconductor element directly without via the  
5 circuit substrate.

10           13. A semiconductor element cooling  
apparatus substantially as hereinbefore described with  
reference to and as illustrated in the accompanying  
drawings.

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**Relevant Technical Fields**

- (i) UK CI (Ed.M) H1R (RBK), H1K (KPDB, KPDX)  
(ii) Int CI (Ed.5) H05K 7/00, 7/20, H01L 23/00, 23/34, 23/36, 23/367, 23/46, 23/467, 23/473)

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI

Search Examiner  
J DONALDSON

Date of completion of Search  
23 JUNE 1994

Documents considered relevant following a search in respect of Claims :-  
1 TO 6

**Categories of documents**

- X: Document indicating lack of novelty or of inventive step. P: Document published on or after the declared priority date but before the filing date of the present application.  
Y: Document indicating lack of inventive step if combined with one or more other documents of the same category. E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.  
A: Document indicating technological background and/or state of the art. &: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2174193 A	(ICL) see page 1, line 45 - page 2 line 7	1
X	GB 1341294	(TEXAS) see page 3, lines 18-33	1
X	EP 0485281 A	(MATRA) see Figure 2	1
X	EP 0219657 A2	(IBM) see column 3 line 53 - column 4, line 29	1
X	WO 93/06340 A1	(BENTON) see page 6 line 24 - page 7 line 22	1
X	US 5077601	(HATADA) see Figures 1-46	1
X	US 4699208	(WOLF) see column 4 line 17 - column 5 line 29	1
X	US 4541004	(MOORE) see column 2 line 46 - column 4 line 6	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

**Patents Act 1977 SECOND SEARCH**  
**Examiner's report to the Comptroller under Section 17**  
**(The Search report)**

Application number  
GB 9410135.9

**Relevant Technical Fields**

- (i) UK Cl (Ed.M)     HIR (RBK), HIK (KPDB, KPDX)  
(ii) Int Cl (Ed.5)     HO5K 7/00, 7/20; HOIL 23/00, 23/34, 23/36,  
23/367, 23/46, 23/467, 23/473

Search Examiner  
J DONALDSON

Date of completion of Search  
23 SEPTEMBER 1994

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-  
7 TO 12

(ii) ONLINE DATABASES: WPI

**Categories of documents**

- |   |   |
|---|---|
| <b>X:</b> Document indicating lack of novelty or of inventive step.   | <b>P:</b> Document published on or after the declared priority date but before the filing date of the present application.        |
| <b>Y:</b> Document indicating lack of inventive step if combined with one or more other documents of the same category. | <b>E:</b> Patent document published on or after, but with priority date earlier than, the filing date of the present application. |
| <b>A:</b> Document indicating technological background and/or state of the art.   | <b>&amp;:</b> Member of the same patent family; corresponding document.   |

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0458500 A1 (AT & T) see column 2 line 24 to column 3 line 7	7-12
X	WO 93/06340 A1 (BENTON) see page 6, line 24 to page 7, line 22	7-12
X	US 5077601 (HATADA) see Figures 1 to 46	7-12

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